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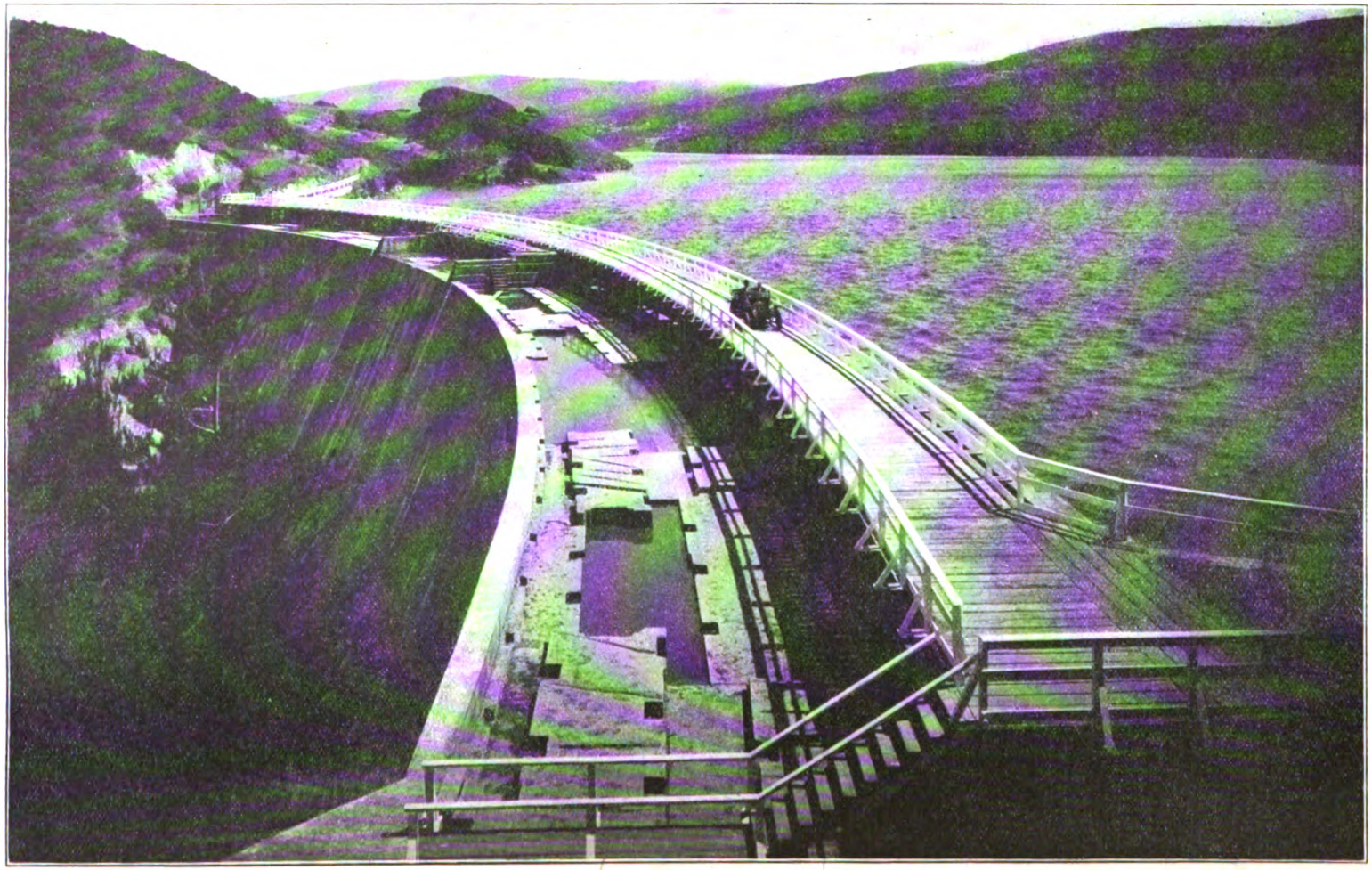

CRYSTAL SPRINGS DAM AND RESERVOIR, A PART OF THE WATER-SUPPLY SYSTEM FOR WHICH SAN FRANCISCO HAS OFFERED THE SPRING VALLEY WATER CO. $38,500,000.

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EDITORIAL

MR. DARROW has been adjudged 'not guilty' by a jury of his peers. The Scotch verdict 'not proven' has many points in its favor.

WE are certainly progressing. The Interstate Commerce Commission some time ago declared that an upper berth in a sleeping-car should be cheaper than a lower, and now the city of Portland has passed an ordinance providing for a three-cent fare for those unfortunates who dangle from straps in street-cars. The street railway company threatens to carry the matter into the courts, while manufacturers of rolling stock await the outcome with interest.

CONGESTION of street-car traffic is by no means confined to cities of the United States. At Lima, Peru, the *Empresas Eléctricas* is in difficulties over passengers on the running-boards, just as are traction lines at Washington, D. C. Last fall we saw in a Japanese paper a plaintive letter from 'Pro Bono Publico' protesting against the crowding of municipal cars during rush hours and recalling that before municipalization of the lines it was stated that thereafter the service was to be improved. Unfortunately, human beings are creatures of habit, and they all like to go home at the same hour.

CONGRESSIONAL investigation of the muddled conditions in the Department of Agriculture has made even more evident the fact that all difficulties have arisen from poor administration. Messrs. C. G. Elliott and A. D. Morehouse, the committee finds, were treated unjustly and harshly. Not only did the Government suffer no injury nor did these engineers make any personal profit from the technical irregularities for which they were dismissed, but the Government work was actually advanced and, furthermore, the shortage in funds for the work was due to irregularities in accounting on the part of higher officials. There have been few clearer cases of saving the 'higher ups' at the expense of the man in the field. A complete and thorough cleaning up of the Department of Agriculture is badly needed, but there seems to be small probability of it being effected. In the meantime, engineers will congratulate Messrs. Elliott and Morehouse on their vindication, and if the President will not dismiss an incompetent Secretary, the President must be held responsible for his mistakes.

GERMAN scientists are hard at work on a scheme to iron out the wrinkles in the calendar. The new day is to have 100 hours of 100 minutes each, while the week, by dropping Saturday from the list, will have but six days. Six weeks will constitute a month and ten months a year. It is admitted that this leaves the year shy some five days or so, which was a real stumbling-block in the onward march of progress until some genius suggested that these odds and ends of days might be used for holidays, which didn't county for much anyway, so all was harmonious again. Just what will become of the extra day in leap year seems still to be on the list of unsolved problems. We are not

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quite able to decide whether we like the new calendar or not. Saturday has always seemed a good sort of a day, and Saturday afternoon especially may be put to a variety of uses that have many points in their favor. If any day should be selected for decapitation, why not get rid of Monday? It is a dismal day at best; 'blue' Monday conjures up visions of roseate Sunday nights, gone but not forgotten. The thirty-six-day, six-week month, however, fills us with apprehension. It surely is the product of the Machiavellian brain of some plutocrat who has a large number of employees drawing monthly salaries. With the new calendar in force there would be two less months and consequently two less salary payments in each year. The landlords would ask for an increase in rent, which is a little way they have, while the demon hunger would insist upon its usual allowance of proteins and carbohydrates. It appears that our old friend, the increased cost of living, is still doing business at the same old stand.

COMPLETION of the maiden voyage of the motor vessel *Selandia* marks an epoch in ocean transportation. The round trip covered a total of 21,500 miles. In spite of the fact that the vessel embodied many new principles that were strange to the engineer crew, the only repair work necessitated during the entire trip involved a slight adjustment of the exhaust valves, consuming but fifteen minutes time. The fuel consumption fell below that estimated by the builders, as on the home voyage the *Selandia* averaged ten nautical miles an hour on a consumption of 8.5 tons of oil per day, and the charge of Borneo oil taken on board at Singapore is stated to have been sufficient for the round trip. A thorough investigation was made by Lloyd's representatives at Copenhagen at the completion of the journey, and they have reported that everything was in perfect order and that no parts had suffered undue strain. The temperature of the water used for cooling in the cylinder jackets at no time exceeded 40.6°C., although 53°C. had been previously established as a maximum. The results achieved by the *Selandia* have been so satisfactory that the Danish East Asiatic Company has placed an order for three additional motor vessels of greater tonnage. It is stated that the British Government is about to appoint a commission of scientists to consider the introduction of oil motor vessels in the British navy.

APPOINTMENT of Mr. M. M. O'Shaughnessy as city engineer to succeed Mr. Marsden Manson, is announced. The salary ordinarily paid in such an office is such that except in a few cases of self-sacrifice, none but mediocre men are willing to accept the position. Mayor Rolph, however, has upset precedent and, by offering a salary more in keeping with the earnings of a skilled engineer in private practice, has obtained the services of a man eminent in his profession and an acknowledged expert on the subject of water supply in all its phases. San Francisco is to be congratulated in obtaining the services of one so well qualified to undertake the work in hand.

Bessemerizing Asphalt

Asphalt, as a by-product of the oil industry, is now being produced in such quantities as to nearly fill the domestic demand, as is shown by the uniform decrease in importation. The first

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use to which asphalt was put in the United States was in the manufacture of asphalt varnishes and 'japaning' metals, the asphalt having been imported from the region of the Dead Sea and elsewhere in the Near East. Trinidad lake asphalt, found in an impure state mixed with water and clay, is largely used as a surface dressing for street paving. The oilfields of California and Texas are now furnishing a large quantity of asphaltic residues which are finding a great variety of applications. Mr. Walter P. Jenney was among the first to conceive the idea that by the application of an air-blast the asphaltic material could be 'bessemerized' in such a way as to make it sticky and to a certain extent elastic. Elastic material for roofing and even substitutes for rubber in automobile tires have been obtained from asphaltic residues by this blowing process or by treating with sulphur. This sulphurization of asphalt has even been applied with good effect to elaterite and similar hard asphalts from eastern Utah. The extension of this interesting bessemerizing process holds out attractive possibilities—for example, that the same raw material may be used in both the elastic tire of the automobile and the road over which it runs. The chief feature of the asphalt industry in 1911, as shown by an advance chapter, by Mr. David T. Day, from 'Mineral Resources,' published by the United States Geological Survey, is the great extension of the use of residues from the asphaltic varieties of petroleum as binders in the surfaces of macadam roads in order to prevent the rapid deterioration of these roads from automobile traffic. The asphalt used for this purpose showed a gain in quantity from 159,424 tons in 1910 to 234,951 tons in 1911.

Navy Yards and Labor

Scientific management seems doomed to be barred from American navy yards, as the Senate Committee on Education and Labor has favorably reported a bill for its abolition. Great pressure has and will undoubtedly be brought to bear by the trades unions in order to have the measure become a law. They have always bitterly opposed piece work or any other device that, while enabling one workman to make more money than another, could be used for 'speeding up' the slow man. The tendencies of the trades union of today are along socialistic rather than individualistic lines, and they limit their usefulness by frequently seeming to prefer, through limitation of output and encouraging inefficiency, to make the more skilled workmen come down to the level of the less skilled, rather than to help the less skilled man improve. Efficiency in shop management is undoubtedly the greatest problem with which manufacturers have to contend; their greatest handicap being the opposition of their employees, collectively and individually, to any improvements, particularly to the introduction of time and labor-saving machine tools and methods of manufacture necessary to increase the output and lower the cost of production. Scientific management, however, in its various modified forms, is gradually finding its way into many of the larger manufacturing establishments, and there is no doubt that it will ultimately prevail, provided that the manufacturers themselves deal fairly with their men and do not attempt to make the record maximum production of yesterday the basis for fixing the minimum production of today. It is the fear of this, doubtless, that stimulates the unions to opposition.

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Earnings of Engineers

The earning power of engineering graduates is a topic that has evoked much discussion since the publication of statistics by the engineering division of the Iowa State College, of which an abstract appeared in the August issue of *Western Engineering*. According to the report, the average engineering graduate may expect to receive $2000 per year eight years after graduation, $3000 per year fifteen years after graduation, $4000 per year twenty-two years after graduation, and $5000 per year twenty-eight years after graduation. This seems too good to be true, and Mr. W. J. Sullivan, writing in *Engineering and Contracting*, has very properly taken exception to this statement, basing his opinion on statistics of the total number of engineering graduates turned out by all engineering schools, now aggregating more than 5000 annually. Young engineers have become a drug on the market, and it is not surprising that many of them, disgusted at the lack of encouragement and opportunity offered by strictly professional pursuits, should turn to commercial life in search of a living and an opportunity for advancement which is the natural ambition of every man. It would appear more important to gather statistics as to the occupations that enable the engineering graduates to earn the reported income than to assume that every engineering graduate continues in professional pursuits for the balance of his life. After all, the one and only question is whether an engineering education makes it easier for a man to keep his head above water in the daily struggle for existence. Mr. Sullivan speaks of an engineering graduate who became an automobile salesman as one would of a lost soul, and indeed most of those engineers whose work is entirely professional are apt to look upon the engineering graduate engaged in commercial pursuits as one who has irretrievably lost caste with his professional brethren. On the contrary, the work of a commercial engineer in the employ of a manufacturer of engineering apparatus calls for quite as comprehensive technical knowledge as does the ordinary sort of professional work. While the professional engineer is apt to specialize, the commercial engineer is like the country medical practitioner who may be called upon within twenty-four hours to prescribe for any ailment ranging from a cold in the head to spinal meningitis. We are of the opinion that an engineering graduate is far better fitted to work out his own salvation than a B.A. in social sciences, whether he follows up his engineering training or goes into the grocery business. This is a mechanical age, and the occupations of mankind today in which a preliminary training in engineering is not a decided advantage are few and far between. If the course prescribed by the engineering schools placed more stress upon the economic and administrative side of engineering, the value of the training would be greatly enhanced. The universities and other educational institutions would render a real service by compiling statistics covering the average financial condition of students in every field and thus enable comparisons to be made as to the actual value in net results produced of each course of study. It is relatively unimportant what occupation a man may follow after graduation; the question is not, how much do engineers earn, but what course of study produces the highest average earning power.

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REVIEW OF THE MONTH

LEGISLATION regulating traffic through the Panama canal has been the focal point of greatest interest during the month, not only for Americans, but for the people of the entire civilized world. The bill as finally agreed upon by the Senate and House of Representatives and signed by the President, provides free passage for American ships engaged in coastwise trade, American registry for American-owned foreign-built ships engaged exclusively in foreign trade, no tariff on foreign shipbuilding material for use in the United States, 'trust'-owned ships denied the use of the canal, railroads prohibited from owning competing waterway lines operating "through the canal or elsewhere," and a 'one-man' government for the canal and Canal Zone.

THE first clause was the cause of a protest from Great Britain on the ground that its enactment would be a violation of the Hay-Pauncefote treaty. Many members of Congress shared this belief, notable among them being Mr. Elihu Root, whose eminence as a lawyer and long experience in international affairs make his opinion and judgment worthy of serious consideration. The President has recommended the passage of a joint resolution declaring it contrary to the intent of the United States to violate any of the provisions of the Hay-Pauncefote treaty, and giving jurisdiction to the United States district courts to pass on the validity of any claims that might be made by a foreign nation that treaty rights had been violated. That free tolls have met with popular approval there is no doubt, but whether the Hay-Pauncefote treaty has or has not been violated is a grave question. The undoubted popularity of the clause, together with the imminence of the fall elections no doubt had their share of influence, but it may be noted that the original provision for free tolls for all American vessels was, after Great Britain's protest, changed so as to permit free passage only to ships in the coastwise trade; a traffic already prohibited to foreign ships. The clause barring railroad-owned ships created hardly less discussion. The Pacific Mail company will be the one most affected by this provision, but the Canadian Pacific Railroad Company had made extensive plans for placing a larger fleet in commission on both the Pacific and Atlantic oceans by the time the canal was opened for traffic. Apparently the former record of the Pacific Mail company for effectually throttling sea competition for the benefit of the transcontinental railroads has arisen like Banquo's ghost to haunt it in this hour of penitence. Twelve million dollars had been raised for the building of four new steamers, but the project has now been abandoned. Retaliatory measures have already been taken by the directorate of the Suez canal, in which the British Government is a large stockholder. The opening gun of the fight comes in the form of a reduction in the tolls for loaded ships of 50 centimes, the new rate being 6.25 francs, which is the exact equivalent of the Panama maximum rate of $1.25 per ton. The consensus of opinion re-

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garding rates is that if the Panama canal is to be a financial and commercial success, they should be lower than at Suez, so if Great Britain should appeal to The Hague tribunal and fail, a rate war might be the next step.

COMPLETION of public work is almost invariably attended by a valedictory of criticism and investigation, after which the wave of attack subsides, to be forgotten in some interest which claims public attention for the moment. Job is said to have been a very patient man, meekness was the specialty of Moses, while Mr. Joseph H. Choate was noted for his tact and diplomacy, yet we are inclined to doubt whether a man or men combining the qualities of all three could conduct a large public engineering project without treading on the toes of many people. The Los Angeles aqueduct is no exception to the rule, the most serious attack being in the form of a circular issued by the Association of American Portland Cement Manufacturers criticizing the cement and concrete work which forms a large portion of the entire aqueduct. According to the report, the cement which was manufactured by the municipally built and operated plant at Monolith, will not pass standard specifications; the material used is not fit for the manufacture of a true portland cement; and when used as an adulterant for portland cement, defective work has resulted that will ultimately have to be torn out and replaced. In support of these statements, some thirty-eight photographs of various defects in the cement work are appended as exhibits, together with many analyses and reports of tests. Los Angeles has been in a political turmoil for some years, owing to the activity of the Socialist party. The active campaign for the mayoralty conducted by Mr. Job Harriman and his strenuous defense of the McNamaras are still fresh in the mind of the public. The aqueduct has been the object of attack by Socialists for several years, for dearly as they profess to love municipal ownership, they object most strenuously to furnishing a day's work for a day's pay. This principle has been so successfully enforced in the construction of the aqueduct that it will be finished on time at a cost well within the amount of the appropriation. It would appear that the cement manufacturers were unfortunate in the selection of men to conduct the investigation, as both Messrs. Finkle and Loomis are identified with the Socialists, and the latter, who guided the party over the field, is a discharged employee of the aqueduct. The report purports to have been made without bias and with a sole idea to present the facts as they exist, yet we cannot refrain from quoting the following: "In the present report, we are only dealing with the defects due to inferior cement and concrete work, and while there are many other fundamental blunders committed on the work, these are matters which, while we have knowledge of them, will not be discussed in the present report." This 'side' remark, as it were, effectually disposes of any claim to impartiality that the report may make, as it clearly shows not only bias but animus on the part of the examining engineers. Had it been true that they were concerned with the cement work only, the latter part of the statement would not have been made at all. It reminds us of the man who effectually disposes of another by saying, "He is a good fellow, *but*——" Innuendo is often more damaging than direct statement. It should also be remembered that at the

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time the aqueduct was in the market for cement, much dissatisfaction was expressed at the prices at which portland cement was offered by the manufacturers, and the Monolith plant was built by the city on that account. If the concrete work done on the aqueduct can be proved defective, due to the use of cement manufactured in the municipal cement plant, "I told you so" will probably adorn the stationery of every private portland cement manufacturer in the association. Portland cement manufacturers, in the interests of their own business, are strenuously opposing the public manufacture of cement and admixture of tufa. They are also especially interested in interfering with the sale of the cement plant when the aqueduct is completed, and are equally opposed to its continued operation by the city in the event of the sale not being consummated. On the other hand, engineers of public works must expect, and may be fairly asked, to stand the criticism of reputable members of their profession. A public work is too big and too important to permit it to pass without examination by those not concerned in its building, and if the cement or other work on the aqueduct is bad, the sooner the fact is made known the better. Newspaper controversies are undignified, and Messrs. Wm. Mulholland and J. B. Lippincott have refrained from making public any reply. The best refutation of such charges will be to put the aqueduct to work, and as the entire project will be completed early in 1913, under the estimates, the public will not have long to wait before being able to see whether there is any basis for the allegations made. Forty-eight miles of the aqueduct now has water in it, which looks as if the charges would not hold water, while the aqueduct certainly will.

PANAMA-PACIFIC EXPOSITION matters will soon show evidence of progress, as it has been announced that bids will be received for the first structure within a few days. Plans call for an administration building, three stories in height, to cost approximately $60,000. It will be a frame structure, covered on the outside with staff and plaster, 150 feet square, with an interior court 104 feet long and 58 feet wide. The style will be early Californian, to harmonize with other buildings to be erected later on the exposition site. The offices of the auditor, treasurer, railroad, installation of exhibits, admissions and concessions, information and telegraphy departments will occupy the first floor, the north wing of which will be occupied by the police and exposition guards department, while the south wing will be used by the emergency hospital. The second floor will be occupied by the engineering, architectural, and mechanical departments and the offices of the executives actively in charge of the exposition construction work. The third floor will be used by the photographers, blueprinting department, and color studios. Within a period of six days the dredges occupied in filling a portion of the fair site have added 30,000 cubic yards of sand to the fill. The Harbor View site, covering an area of 71 acres, is practically completed.

HETCH-HETCHY and San Francisco's water-supply is the subject of an extensive report by Mr. John R. Freeman which has been filed with the advisory board of Army Engineers appointed to act in behalf of the Federal Government. Mr. Freeman has answered at length all arguments against the acquisition of the Hetch-Hetchy source of water supply. Even

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the nature-lovers are not slighted, as Mr. Freeman proposes to cater to the esthetic side of mankind by including in the proposal the construction of a magnificent boulevard, which will start at the dam and encircle the lake, thus duplicating such scenes as may be seen in Norway and Switzerland, and encouraging the 'see America first' movement. The project as proposed contemplates an immediate supply of 250,000,000 gallons per day, with a possible increase to 500,000,000 gallons. The surplus over present needs may be used for irrigation purposes until it is required for municipal supply. A gravity flow system will be effected, thus saving the expense of building and operating pumping stations. The importance of the application of the gravity system may be better realized when it is understood that the approximate cost of raising 1,000,000 gallons of water one foot high is three cents; the cost of raising 400,000,000 gallons per day one foot would pay the interest on nearly $20,000,000. Plans submitted are somewhat similar to those of the Los Angeles aqueduct. Water is provided from a source which has an entire granite bedrock, and from the time that it will pass to the intakes, which will consist of concrete-lined tunnels and cement-lined steel pipes, the water will be subjected to a minimum of exposure, thus ensuring its being absolutely free from any form of contamination. The water itself is of exceptional purity. On a basis of 250,000,000 gallons daily, the quantity of water developed will be approximately 50 per cent more than the capacity of the Los Angeles aqueduct. According to the requirements of the metropolitan area of San Francisco in the past, and projecting the line into the future, 400,000,000 gallons of water per day will no doubt be required by the end of the present century. Mr. Freeman's estimates show that the original work on the Hetch-Hetchy system for supplying the needs of the present generation will cost approximately $35,000,000 to build dams, reservoirs, and pipe-lines for developing a flow of 400,000,000 gallons per day to the Crystal Springs reservoir and $5,000,000 additional for meeting the expense of bringing the water to San Francisco from Crystal Springs. This is well within the $45,000,000 bond issue which has been already voted for this project by the people.

ACTION has been taken by the Advisory Water Committee of San Francisco on the proposed purchase of the Spring Valley Water Company resulting in an offer being made of $38,500,000, subject to ratification by the voters. In addition to this amount, the company is to be allowed to retain the impounded moneys, amounting to $1,300,000, covering the various water-rate suits still pending before the courts. In view of these facts, special interest is attached to the famous Crystal Springs dam, which forms the frontispiece for the month. It is the main gateway for the Crystal Springs reservoir in San Mateo county, where ultimately 45,000 million gallons of water will be stored. The interlocking-block system was used in constructing the dam. The blocks are about 40 feet long, 30 feet wide, and from seven to nine feet high, and are built in place alternately. The dam itself is 145 feet high, the base being at an elevation of 135 feet above tide. The present storage capacity of the reservoir is 19,000 million gallons, but provision has been made for an increase in height of 43 feet, which would give an ultimate capacity of 45,000 million gallons.

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Economics of Power Transmission Lines

By ALFRED STILL*

"TRUE engineering is based on economics." These are the words of R. D. Mershon; and every engineer does or should realize the truth of the statement. On the other hand, there are many engineering undertakings, or portions of such undertakings, in which this fundamental principle has been disregarded. In the case of transmission lines a certain system, or an exceptionally high pressure may have been adopted because of its peculiar interest as an engineering problem; or duplicate lines, spare generating plant, and costly automatic gear may have been installed to ensure continuity of supply, apart from the economic value of such increased protection against possible interruption. This, however, is not engineering in the commercial sense. The determination of the economical size of conductors for the transmission of any particular amount of current, in accordance with the principle generally known as Kelvin's law, is now well understood; but this is a very small part of the problem to be solved by the transmission line engineer. An attempt will be made in this article to deal with the economics of the overhead power transmission line from a broad practical standpoint. Some approximate figures for use in getting out preliminary estimates will be given; and in the working out of any numerical examples it will be assumed that the principles governing the selection of the most economic size of conductor require no explanation. When considering any scheme of power transmission from a generating plant of limited output, it is important to bear in mind that it does not pay to cover distance greater than that within which there are reasonable prospects of supplying all the power available at the generating station. The importance of this principle should be fairly obvious; yet there are instances which prove that it has been disregarded.

Choice of System.—On this continent it is usual to transmit electric power by means of three-phase alternating currents, the periodicity being 25 or 60 cycles per second. In Europe the Thury system of continuous current transmission at high voltages has met with success; it has much to recommend it, and there appear to be no reasons why it should not meet with equal success on this continent; but it is probable that three-phase transmission, at pressures even higher than those now in use, will hold its own for a considerable time to come.

Type of Transmission Line.—The structures for supporting the overhead conductors may be of wood, steel, or reinforced concrete. The wood supports may be of the ordinary single-pole type spaced 100 to 300 ft. apart, or they may be **A** or **H** frames built up

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of two poles suitably braced, and capable of supporting longer spans. The steel poles may be of the simple tubular type, or built up of three or four vertical tubes or angles. The more common construction for high-pressure transmission lines consists of light-braced towers with wide rectangular bases, except where the 'flexible' type of structure is adopted. These flexible towers are modeled generally on the **A** and **H** types of double wood pole supports. It is by no means an easy matter to decide upon the most suitable type of supporting structure to be used on any particular transmission scheme. In some cases a composite line including two or more types of support may be found advantageous. Among the factors influencing the choice of the supporting structures may be mentioned the character of the country, the means and facilities of transport, climatic conditions, the nature of the soil, and the scarcity or otherwise of suitable timber in the district through which the line will pass. In undulating or hilly country, advantage may frequently be taken of the heights, by erecting upon them comparatively low and cheap structures and spanning the depressions or valleys without any intermediate supports. The engineering features must, however, be very carefully studied in all such exceptional cases.

Length of Span.—Even when the type of structure has been decided upon, the height, strength, and cost of the structures will be dependent upon the distance between them. The determination of the average length of span is indeed a very important economic question. The material of the conductor will, to some extent, influence the choice of span length, because aluminum conductors will usually have a greater summer sag than copper conductors, and this will necessitate higher supports to give the same clearance above ground at the lowest point of the span. In considering span length, the first cost of the individual support is not the only question which has to be taken into account; the cost of maintenance is almost equally important. The longer the span, the fewer will be the points of support; and if the line is well designed and constructed, there should be less trouble through faults at insulators. Again, where rent has to be paid for poles placed on private property, it is generally the rent per pole apart from the size of pole which has to be considered, and this is another factor in the determination of the best length of span. In level country, the economic span for steel tower construction is usually in the neighborhood of 550 ft. If substantial, braced, wooden towers of considerable height are used in a district where such structures can readily be constructed, the economic span would probably be greater than 600 ft. It is hardly necessary to mention that, when comparing costs of various kinds of supports, the relative life and cost of upkeep of the poles or towers must be taken into account.

Effect of Span Variations on Cost of Steel Towers.—The height of towers in level country depends on (1) the minimum clearance between the lowest conductor and ground when the sag is greatest; (2) the voltage, since this has an effect on the spacing of the conductors and also to some extent on the clearance above ground level; and (3) the maximum sag. This last is determined by the lengths of span, the material and size of the conductors, the range of temperatures, and weather conditions generally. For the purpose of rough approximations suitable for

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preliminary estimates I have made use of the empirical formula

$$H = 35 + 0.3\ V_k + 0.6\ (\tfrac{l}{100})^2 \qquad (1)$$

This gives the approximate overall height of towers in feet. The voltage V_k is expressed in kilo-volts and the length of span l, in feet. The formula is especially applicable to towers carrying a duplicate three-phase circuit. The constants have been worked out on the supposition that there are six No. 0000 aluminum conductors and a grounded guard wire joined to tops of the towers. It is not intended to apply to spans greater than 600 ft. In the case of larger spans advantage is usually taken of inequalities in the ground levels. The cost of steel towers will depend not only upon the height, but also upon the stresses which the tower has to withstand. These again will be dependent upon the size of the wires, the length of span, and the weather conditions. It is probable that, with an increase in height, the cost increases less rapidly than the square of the overall length, but for approximate calculations it is convenient to assume the relation cost varies as H^2. Also, if the weight of a tower measuring 60 ft. overall is taken at 1800 lb., and the price per pound of the finished (galvanized) tower at 5c.,* the cost per tower in dollars is $\frac{H^2}{40}$. (2)

The cost of the flexible type of tower is appreciably less, being about seven-tenths of the cost of of the rigid type with square base, or $\frac{H^2}{57}$. (3)

It is, however, usual to provide rigid strain towers in place of the flexible type at, say, every mile, and as the cost of such structures is about double the cost of the flexible tower, the cost of supports per mile of line may be calculated by assuming $n + 1$ flexible structure per mile, when the actual spacing is n to the mile.

Duplicate Lines.—A point of great importance in connection with power transmission undertaking is the means adopted to guard against interruption of supply. If it is allowed that the least reliable part of a transmission system is the line itself, it is certainly advisable, when circumstances permit, to duplicate the lines; the two sets of conductors being connected in parallel under normal conditions. The best protection against interruption would be afforded by carrying the two sets of conductors on separate poles, preferably by different routes; but this would almost double the cost of the line, and it is usual to carry duplicate lines either on one set of poles, or on two sets of poles erected side by side on the same right of way. As an alternative to the duplication of the lines, the provision of reserve generating plant at the receiving end may be considered, and a comparison should be made between the relative advantages and costs of the various alternatives.

A good example of steam-driven auxiliary plant in connection with hydro-electric power stations, is the recently completed oil-burning steam-generating station of the Southern California Edison Co., situated 25 miles from the city of Los Angeles and capable of connecting in parallel with the 60,000-volt and 30,000-volt systems ordinarily supplied by the Kern river and other hydro-electric generating stations of this company.

Costs of Typical Transmission Lines.—It would be possible to give a large number of figures relating to material

*This cost may be anywhere between 3½ and 6c. per pound.

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and labor costs of completed transmission lines; but the conditions of transport of materials and quality of labor differ widely, and without complete knowledge of these conditions, such figures are liable to be misleading. For this reason two ideal preliminary estimates, one referring to a wood pole line, and the other to a steel line, are here reproduced, in the hope that they may be useful as a basis on which somewhat similar estimates may be shaped.

Preliminary Estimate No. 1.

Wood pole transmission line, 20 miles long, carrying one three-phase line. Line pressure 22,000 volts. Span 130 ft. There is no grounded overhead guard wire; but two telephone wires are carried on the same set of poles. An allowance of 20% is made for extra insulators and fixtures to permit of doubling these on corner poles and in other selected positions.

Preliminary Estimate No. 2

'Flexible' type steel tower line, 60 miles long, with two sets of 3-phase conductors. Line pressure = 80,000 volts. Average span, 480 ft. Spacing between

PRELIMINARY ESTIMATE NO. 1

MATERIALS (EXCLUDING CONDUCTORS)

40	creosoted cedar poles, 35 ft. long, 8 in. diam. at top	$400.00	
48	cross-arms, 3½ by 4½ in. by 4 ft. long	14.50	
96	galvanized-iron braces, 1¼ by ¼ by 28 in. long	9.00	
32	galvanized bolts, ⅝ by 12½ in., with washers	7.50	
8	galvanized bolts, ⅝ by 16 in., with washers		
16	galvanized spacing rods, ¾ by 16 in., with nuts and washers		
48	galvanized lag screws, ½ by 3½ in		
96	galvanized carriage bolts, ⅜ by 4½ in		
1500	ft. galvanized 7-strand 5/16 in. guy wire	12.00	
12	anchor rods with nuts and washers and necessary timber for anchor logs	7.00	
24	galvanized guy clamps with bolts	3.00	
8	galvanized sheet-iron bands to prevent cutting of poles by guy wire	0.50	
12	standard thimbles for guy wire	0.40	
20	galvanized-iron lightning conductors, with bolts	5.50	
20	ground plates or galvanized-iron pipes	8.00	
	Staples and sundries, including allowance for breakages and contingencies	15.00	
80	telephone wire insulators (glass)	10.00	
80	side brackets for same (wood); 5-in. wire nails		
144	H.T. porcelain insulators	36.00	
96	galvanized-iron insulator pins with porcelain bases	14.40	
48	special pole-top insulator pins, with bolts	19.20	
	Total material cost per mile of line		$562.00

LABOR

Clearing 50 ft. on each side of pole line @ $30 per acre	363.00	
Distributing poles and other materials along the line	30.00	
Trimming poles, cutting gains, drilling holes, setting cross-arms	30.00	
Digging holes and erecting poles, including the necessary guying	80.00	
Fixing insulators and stringing wires, including telephone line	90.00	
Supervision and sundry small labor items	30.00	
Loss and depreciation of tools	10.00	
Management and preliminary work	25.00	
Total cost per mile for charges other than materials	$658.00	
Total cost per mile, excluding cost of conductor material		$1220.00

CONDUCTORS

16,000 ft. No. 1 copper conductors (hard-drawn); 700 ft. No. 4 copper for ties (soft); 10,800 ft. No. 10 copper for telephone circuit; 4550 lb. @ $15 per 100 lb.	682.50
Total cost of finished line	$1902.50

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wires, 8½ ft. A Siemens-Martin steel cable, acting as grounded guard wire, joins the tops of all towers. Insulators of the suspension type. No telephone wires. Minimum clearance between lowest H.T. conductor and ground = 40 ft. Cost of right-of-way not included in estimate.

by putting in cheap and possibly unreliable insulators. The curves of Fig. 2 are intended to supplement the figures of the typical estimates. They give approximate costs of transmission poles or towers, with and without insulators fixed in position. These costs are the averages of many actual figures,

PRELIMINARY ESTIMATE NO. 2

MATERIALS (EXCLUDING CONDUCTORS)

10	flexible type, galvanized-steel, A-frame towers @ $85	$850.00	
1	galvanized-steel strain tower	170.00	
	concrete foundations where necessary	80.00	
5600	ft. 7/16 in. galvanized Siemens-Martin steel-strand cable for guard wire and head guys on half-mile flexible towers	128.00	
4	anchor rods, complete with clamps and thimbles for guy wire	4.00	
90	sets of suspension-type insulators, including strain insulators and small allowance for breakages, complete with clamps	338.00	
	Sundry small items or special material	50.00	
	Total material cost per mile of line		$1620.00

LABOR

	Clearing 60 ft. on each side of line at average cost of $25 per acre	$363.00	
	Distributing towers and other materials along the line	100.00	
	Foundations for towers	75.00	
	Assembly of parts and erection of towers	160.00	
	Fixing insulators and stringing wires	170.00	
	Supervision and sundry small labor items	50.00	
	Allowance for loss and depreciation of tools	15.00	
	Allowance for management and preliminary work	35.00	
	Total charges other than materials per mile		968.00
	Total cost per mile not including conductor material		$2588.00

CONDUCTORS

	No. 00, hard-drawn, stranded-copper conductors; small amount of No. 2 soft copper for occasional ties; special clamps, shields, jointing materials, etc.; 13,350 lb. @ $15 per 100 lb		2002.00
	Total cost per mile of finished line, not including right-of-way		$4590.00

The cost of insulators increases rapidly with the rise of the working voltage. The curve of Fig. 1 gives approximate average prices of insulators complete with pins or suspension links for pressures up to 100,000 volts. The prices are per insulator or per series of insulator units. The suspension type of insulator consisting of a number of units in series is almost universally used for pressures exceeding 60,000 volts. One golden rule which applies to all overhead transmissions is that it is false economy to reduce first cost

and give an approximate idea of the total expenditure per mile of line for various voltages; they do not include any clearing that may be necessary in wooded country, or payments for right-of-way. It is assumed that the conductors are of average size (No. 000 B and S gauge), but the actual cost of the conductors, whatever the size, must be added to the costs indicated by the dotted curves B and D in order to arrive at the total cost of the finished line. These dotted curves, however, do include an amount to cover the labor

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of stringing the wires. The curves A and B refer to wood poles or rigid steel towers (for the higher voltages) carrying three conductors; while curves C and D refer to a single set of poles or towers carrying six conductors. The cost of a line with flexible steel structures for voltages above 44,000 might be about 75% of the costs given by pole or tower. The cost, as previously mentioned, will also depend upon the material of the conductors, as a larger or smaller sag will influence spans and height of poles. The weight and diameter of conductors, by affecting the required strength of the supports, will be factors in determining the cost of the complete line, apart from any dif-

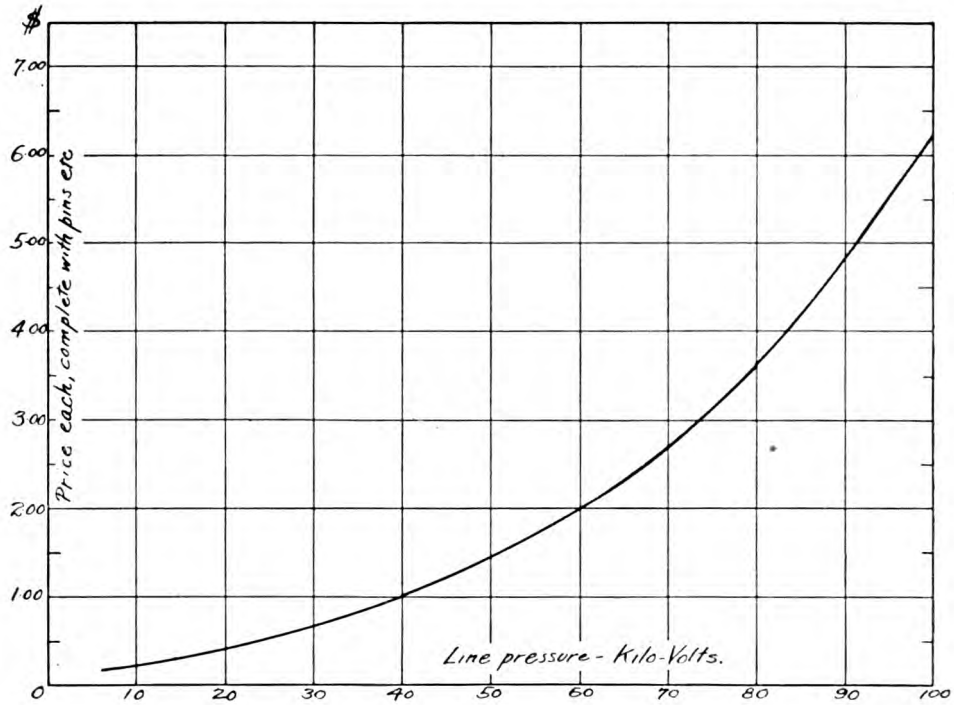

FIG. 1. COST OF INSULATORS FOR VARIOUS VOLTAGES.

curves A and C. It is understood that the curves of Fig. 2 give only an approximate indication of the probable capital expenditure on the line. The actual cost will depend upon the character of the country, the nature of the ground, and other local conditions such as cost of labor and facilities for transportation. These, together with the weather conditions, force of wind and possible loading of wires with sleet or ice, will determine the most economical span and the average height of ference in the value of the conductors themselves. The actual cost of stringing very light or very heavy conductors will also differ from the average amount allowed for the purpose of plotting the curves. The number and style of lightning conductors, if any, and whether or not one or more grounded guard wires are strung above the conductors will obviously modify the average figures. Although steel or concrete poles, or steel towers, will generally be found more economical than a

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wood pole line for voltages above 44,000 on account of the heavier insulators, wider spacing between conductors, and generally greater height of support, it does not follow that wood poles or wood-pole structures may not prove economical, even for comparatively high voltages, in countries where suitable timber is plentiful and the ready means of transportation and erection of steel towers are wanting.

Steel structures may be either galvanized or painted; the extra cost of galvanizing should be compared with the cost of painting periodically, say every third or fourth year. The cost of concrete poles will usually be between 50 and 80c. per 100 lb. weight. A pole 35 ft. high of square section 6 by 6 in. at top and 12 by 12 in. at bottom would weigh about 2000 pounds.

The cost of foundations for towers varies greatly. In the case of fairly high steel towers with wide square bases in soil not requiring the use of concrete, the cost of excavating, setting legs, and back filling, not including erection of towers, will generally be between $10 and $20 per tower.

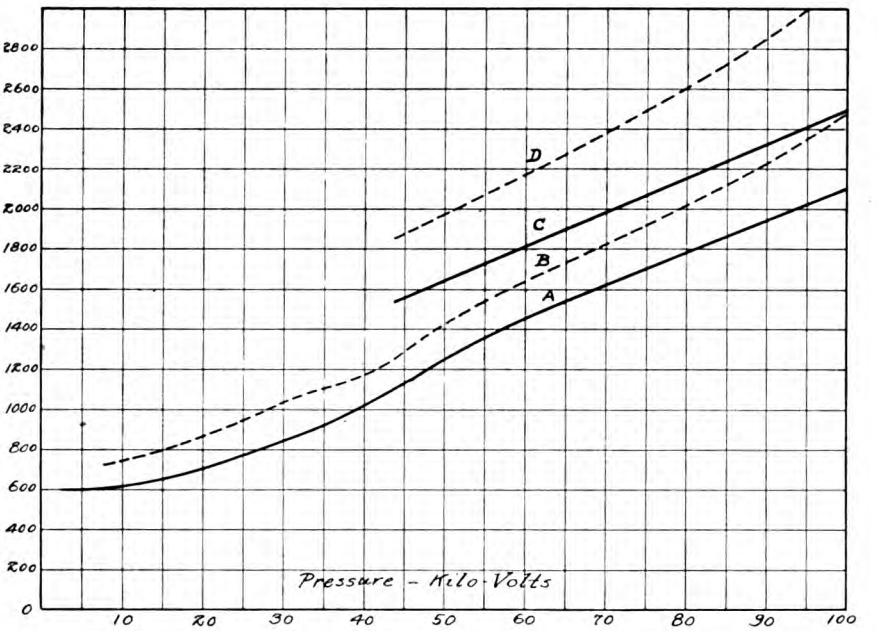

FIG. 2. COST IN DOLLARS PER MILE OF TRANSMISSION LINE COMPLETE, NOT INCLUDING COST OF CONDUCTORS, RIGHT OF WAY, AND CLEARING GROUND IN WOODED COUNTRY.

A—Single 3-phase line without insulators or wires.
B—Ditto, including insulators and stringing but not cost of wires.
C—Same as A, but for double 3-phase line on single set of poles or towers.
D—Ditto, but including insulators and labor stringing wires but not cost of wires.

Cost of Conductors.—The capital expenditure on conductors will depend upon the material and the total weight. It is not proposed to discuss, in this article, the relative merits of copper and aluminum as conductor materials, but it may be well to point out that although, at the present market values of these metals, the use of aluminum may lead to some saving on first cost, there are many engineering points to

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be most carefully considered before definitely adopting either metal. The weight of the conductors necessary to transmit a certain amount of power over a definite distance will obviously depend upon the voltage, but apart from the engineering difficulties encountered at the higher voltages, there are economic considerations which determine the maximum voltage suitable for any given conditions. Among these may be mentioned a possible increase in the cost of generating plant for the higher pressures, the greater cost of step-up and step-down transformers and of the control apparatus, together with the line insulators, entering bushings, etc. The transmission line poles or towers will also, as previously mentioned, cost more for the higher pressures, because of the wider spacing between conductors. Then again, with the extra high pressures, the increased losses through leakage over insulators and possible corona losses may be quite appreciable.

Given a definite amount of power to be transmitted, and a definite line pressure, the current can be calculated; and the economic conductor cross-section, and therefore the weight and cost of the conductors, will be directly proportional to this current. It is only of recent years that this fact appears to have been generally recognized, and yet, so long ago as 1885, in his Cantor lectures delivered in London, George Forbes said: "The most economical section of conductor is independent of e.m.f. and distance, and is proportional to the current." The determination of the current value to be used in the calculation of conductor sections is a real difficulty. It must not be supposed that even a knowledge of the load factor is sufficient by itself. The load factor being the ratio of average load to maximum load, does not give the relation between the average I^2R loss and the I^2R loss of maximum output. The power lost in the conductors of a constant potential supply is proportional to the square of the power transmitted. On the basis of the average hydro-electric load curve, if the load factor is 50%, the load on which the average transmission line losses should be based, being the square root of the mean of the square of the power, will probably be found to be more nearly 60% than 50% of the maximum load.

Economic Voltage. — Clearly, the choice of the transmission voltage is a very important matter; but as it is possible to determine the proper voltage on purely economic grounds, the use of exceptionally high pressures merely because of their interest from an engineering point of view, should be discouraged. On the other hand, it would appear that most transmission line troubles occur on lines working at pressures between 30,000 and 80,000 volts; and an important consideration to bear in mind is that more trouble may be experienced with heavy currents than with high voltages, owing to the more serious effects of interruptions or transient disturbances when the current is large, so that greater security may sometimes be obtained by increasing the voltage with a view to reducing maintenance and operating costs. A remarkable instance of high pressure being used for a short-distance transmission occurs in Germany at Lauchammer. This is the first 110,000-volt installation in Europe. The line is only 35 miles long, but the power to be transmitted is considerable, being 20,000 kw. The engineers claim that, owing to large fluctuations expected through rolling-mill load, low voltages would

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be uneconomical. Under ordinary circumstances, the trend of modern practice would indicate something above about 10,000 kilowatt appear below:

The figures given in the accompanying table are approximate costs for a

	Transmission-Line Voltage:		
	30,000	60,000	100,000
Hydraulic works outside power-station buildings	$15.00	$15.00	$15.00
Power-station building, including excavations	5.00	5.06	5.10
Receiving-station building	1.00	1.03	1.05
Switch-gear (both ends)	1.20	1.35	1.70
Electrolytic lightning arresters	0.34	0.66	1.20
Transformers (both ends)	2.50	2.90	3.50
Generaters and exciters	8.00	8.00	8.00
Cables in buildings, entering, bushings, etc	0.40	0.40	0.50
Crane, sundries, and accessories, including preliminary work	2.00	2.10	2.20
Turbines and hydraulic equipment	10.00	10.00	10.00
Total cost per kilowatt	$45.44	$46.50	$48.25

60,000 volts as the best pressure in this case; but when there is little difference between the cost of a 60,000-volt and an 80,000-volt scheme, it is wise to adopt the higher pressure.

When figuring on the best voltage for any particular scheme, the capital cost of all works, buildings, or apparatus which is liable to be influenced by the transmission-line pressure, together with all operating and maintenance charges which may be similarly influenced, must be taken into account. It will usually be found convenient to reduce all such costs or differences of cost to the basis of annual charges.

Costs Other than Tranismission Line, Liable to Be Influenced by Voltage Variations.—The cost of a generating station complete with all plant and machinery, but not including transmission line, may be anything from $20 to $200 per horse-power installed. It will depend on total output, that is, on the size of the station, on location, and transport and labor facilities. The cost of a hydro-electric station will depend on the head of water, the amount of rock excavation, the size of dam, etc.

Approximate costs per kilowatt of medium head hydro-electric power station and sub-station (not including transmission line) for total output of medium head hydro-electric development suitable for a total output in the neighborhood of 10,000 kw., to be transmitted over two outgoing 3-phase feeders. The usefulness of these figures lies mainly in the indication they give of the probable differences in cost with the variation of transmission-line pressure.

Annual Charges Depending on Voltage.—These charges may be summarized as follows:

1. A percentage on all capital expenditure, whether for generating station, transmission line, or receiving stations, which is not constant irrespective of voltage.

2. The yearly cost of the power lost in the transmission line.

3. The yearly cost of power lost in generators and transformers (the efficiency of the electrical plant will not necessarily be the same for all voltages).

4. The yearly cost of maintenance and operation. This may depend upon length of spans in transmission line, and on the necessary plant, switch-gear, etc., to be attended to, and kept in working order.

The percentages referred to under item (1) must include interest on capital invested, and depreciation. The ac-

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companying table gives the percentage to allow for depreciation for various

DEPRECIATION TABLE

(On basis of 5% compound interest earned by money put aside annually.)

Life (yr.).	Depreciation (%).	Life (yr.).	Depreciation (%).
2	48.70	28	1.710
4	23.20	30	1.505
6	14.70	32	1.325
8	10.50	34	1.175
10	7.95	36	1.045
12	6.28	38	0.928
14	5.10	40	0.828
16	4.23	42	0.740
18	3.55	44	0.662
20	3.03	46	0.593
22	2.60	48	0.532
24	2.25	50	0.477
26	1.96		

terms of years. Depreciation, which may include what is sometimes referred to as obsolescence, is the amount to be set aside annually in order to reproduce, at the end of a term of years, the capital originally invested. This term of years is the 'life' of the works or materials on which the percentage depreciation is to be calculated. It is assumed that, at the end of this term of years, the value of such works or materials is nil. It is also assumed that the amount put aside annually earns interest at the rate of 5% compound.

Method of Determining Most Economical Voltage.—Consider the case of a typical medium head hydro-electric power station:

Distance of transmission = 50 miles.

Duplicate three-phase line with copper conductors.

Cost of conductors = $15 per 100 pounds.

Power demanded = 15,000 hp. or 11,200 kw. (It is assumed that this power will be required continuously day and night for industrial purposes, and that it is the probable limit of the water-power available.)

Power factor = 0.8.

Selling price of power = $21 per horse-power-year.

Interest on capital invested, allow 6 per cent.

The economic drop of voltage per mile of single conductor is given by the formula:[1]

$$e_r = 8.1\sqrt{\frac{a \times p}{p_1}}$$

Where p is the price in dollars of 100 lb. weight of conductor (in this example $p = 15$), a is the percentage to cover annual depreciation and interest on cost of conductors, and p_1 is the cost per horse-power-year of the wasted power. The proper value for a may be arrived at by estimating the term of years corresponding to the life of the conductors, at the end of which they are supposed to be of no value. Taking 20 years as the life of the conductors, the depreciation to be allowed according to the table herewith is 3.03, which makes $a = 6 + 3.03$, or, say, 9 per cent.

With regard to p_1, if the demand for power were equal to the available supply from the time of the power-plant being put into operation, the works cost of waste power would be the same as the selling price; but, on the assumption that the supply exceeds the demand during the first five years of operation, and that the cost of waste power during this period is only $7 per horse-power-year.[2]

[1] This and the one or two subsequent formulas are either taken from, or suggested by, an article by me which appeared in the *Electrical World* of September 23, 1911, and in which their derivation is explained.

[2] The actual works costs of the wasted power is always difficult to determine exactly. It must, however, be remembered that even with unlimited power, and no appreciable increase in maintenance and operating charges with increase of losses, the greater capital cost of the plant installed to provide this waste power has to be taken into account and expressed in the form of an annual charge per horse-power wasted, whether this waste occurs in the generating and transforming plant or the line itself.

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The average cost of wasted power during the 20 years life of the conductors is:

$$p_1 = \frac{(5 \times 7) + (15 \times 21)}{20} = \$17.50$$

The economic voltage drop is therefore:

$$e_r = 8.1 \times \sqrt{\frac{9 \times 15}{17.5}} = 22.5 \text{ volts per mile.}$$

A first approximation to the required line voltage may be obtained by the formula

$$V_k = 5.5 \sqrt{\text{distance} + \frac{\text{horsepower}}{200}}$$
$$= 5.5 \sqrt{50 + \frac{15{,}000}{200}}$$
$$= 61.5, \text{ or say } 60{,}000 \text{ volts.}$$

In order to calculate the cost of the line losses, it will be necessary to adopt a figure for the horse-power transmitted, which, when squared, will give the average square of the power during the estimated life of the conductors.

Assuming an average figure for the output during 12 months, a table showing probable demand for power can be constructed as follows:

Period.	Hp. Demanded.	Hp. Squared by Years.
First year of working	5 by 1000	25 by 10^6 by 1 = 25 by 10^6
Second year of working	6 by 1000	36 by 10^6 by 1 = 36 by 10^6
Third year of working	7 by 1000	49 by 10^6 by 1 = 49 by 10^6
Fourth year of working	9 by 1000	81 by 10^6 by 1 = 81 by 10^6
Fifth year of working	12 by 1000	144 by 10^6 by 1 = 144 by 10^6
Remaining 15 years of estimated life of conductors	15 by 1000	225 by 10^6 by 15 = 3375 by 10^6

Total of last column, 3710 by 10^6.

Average, 185.5 by 10^6.

Average hp. for purpose of calculating cost of waste power = $\sqrt{185.5 \text{ by } 10^6} = 13{,}600$ approximately.

When the section of the conductors is such as to satisfy Kelvin's law of economy, the yearly cost of the I^2R losses is equal to the amount representing annual depreciation and interest on first cost of conductors; and the total annual charges on active line material will therefore be:

$$2 \times \frac{I^2R \times p_1}{746} \times 3 \times 1$$

where R is the resistance per mile of conductor. But

$$I = \frac{P \times 746}{\sqrt{3} \times E \times \cos \Theta}$$

where P stands for the horse-power transmitted.

Also: IR = voltage loss per mile = e_r. So that the formula for the total yearly charges on conductors can be written

$$\frac{2 \times \sqrt{3} \times e_r \times P \times p_1 \times 1}{E \times \cos \Theta}$$

which in this example becomes:

$$\frac{2 \times \sqrt{3} \times 22.5 \times 13{,}600 \times 17.5 \times 50}{60{,}000 \times 0.8} = \$19{,}300$$

Closer Estimate of Economic Voltage.—In order to take into account first cost, life, annual maintenance, and operating charges of every portion of the complete undertaking which may be affected by a change in the transmission voltage, the costs, worked out an an annual basis, may be arranged in tabular form as here shown, where the total charges far the 60,000-volt scheme are compared with the estimated charges for an 80-000-volt transmission. In this particular example, the figures are favorable to the higher voltage; but the difference is small.

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It would be useless to repeat the process for a voltage lower than 60,000, because the cost would certainly be higher.

COMPARISON OF COSTS AT DIFFERENT VOLTAGES

Portion of Complete Undertaking Affected by Change of Voltage:	Estimated life (yr.)	Depreciation (from tables)	Depreciation plus 6 per cent. int.	Total Cost. Voltage 60,000	Total Cost. Voltage 80,000	Annual Charges. Voltage 60,000	Annual Charges. Voltage 80,000
Line conductors (copper) of most economic section (annual cost varies as $\frac{1}{\text{voltage}}$)	20	...	...	.....	.....	$19,300	$14,475
Steel tower transmission-line, without conductors, but otherwise complete (from curves, Fig. 2)	18	3.55	9.55	$108,000	$130,000	10,310	12,410
Generating-station buildings	40	0.828	6.828	56,600	57,000	3,870	3,895
Sub-station buildings	30	1.505	7.505	11,500	11,900	863	893
Transformers	18	3.55	9.55	32,500	35,200	3,100	3,360
Switch-gear, including lightning arresters, cables in buildings, and entering bushings	14	5.10	11.10	27,000	34,000	3,000	3,775
Assume unaltered: Yearly cost of power lost in generators and transformers. Yearly cost of operation and maintenance. Right-of-way and clearing.						$40,443	$38,808
Difference in favor 80,000 volts = $1635.							

It will be understood that the accompanying estimate of total annual charges of the two selected voltages does not include any items other than those that are liable to vary with changes in the line voltage. An estimate covering the complete undertaking would, in addition to the items named, have to take account of riparian rights for dam, reservoir, etc., preliminary legal and other expenses; cost of providing proper access for materials to site of works; dam and hydraulic works outside station building; turbines; electric generators and exciters; auxiliary plant; sundries and contingencies.

In the case of a short distance transmission with a line pressure not exceeding 11,000 volts, and the possibility of winding the generators for the full pressure, the relative costs and efficiencies of generators wound for different voltages should be taken into account

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Oil in Internal-Combustion Engines*

By E. T. ADAMS

THE total amount of gasoline contained in a gallon of crude oil is comparatively small, yet this insignificant portion of the whole has led to a new use for oil, which is even now dominating the industry and dictating the methods of refining and the systems of transportation of liquid fuel. Because of the ease with which gasoline can be used in an internal-combustion engine, it has led to a demand for oil for this purpose, to an extent the importance of which is only beginning to be appreciated. One dealer alone out of the many in the Middle West distributed during the past year 50,000 hp. of 2-hp. gasoline engine and 25,000 families by this one agency in this one year have experienced a revolution in their ideals of power production. The first wave of popular demand for gasoline has already exceeded all possibility of supply, but it has left behind a demand for fuel-oil for internal-combustion engines which is likely to dominate the oil industry until long after the natural supplies of crude oil are exhausted. The world has reached the age when oil pre-eminently means power.

I do not mean that oil is to take the place of coal, or that central stations or transportation systems are to derive their power from this source. They may, or may not. Their action will in no wise affect the result. The vital fact is that the farmer, the smaller manufacturer, and the users of moderate units of power, have been educated to the convenience and economy attained by the use of oil in an internal-combustion engine. Oil power is rapidly supplanting animal power on the farm and in the shops and manufactories closely allied to the farm, which work up the farmer's product. The field makes a demand for power which overshadows all others combined, both in volume and in importance to mankind. Those who dwell in cities are apt to be blinded by the glare of their own electric lights, but it is well to remember that the great labor of man is that of providing his daily bread, and in this field the supplanting of power from animals by power from oil, clearly marks the beginning of a new epoch in man's history. A new axiom has been developed—'Oil is power.'

Two-thirds of the world's supply of crude petroleum is produced in the United States. Last year this amounted to 230,000,000 bbl., or approximately 40,000,000 tons. After refining, this product may be grouped, roughly, into five families, two of which comprise more than two-thirds of the whole. These two are kerosene and fuel oil, each amounting to approximately one-third of the total supply of crude. The remaining third is divided between three small families, each amounting to a little less than one-eighth of the total supply: (1) the naphtha family; (2) lubricating oils; (3) paraffine, asphalt, and residuum. Of these, the

*Read before Milwaukee Gas Engine Convention.

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naphtha family is of chief importance, comprising as it does, gasoline, benzine, and naphtha. Probably not over one-third of the oils classed in the naphtha family, or less than 5% of the total oil production of the country, is gasoline. How insignificant this is as a source of oil power, is at once apparent when we realize that the animal power of the farm, and the expensive and inconvenient sources of power now used by the small manufacturer aggregate in total horse-power an amount greater than that of all railways, steamships, and central power stations of the world. With the naphtha family, the lubricating, and the paraffine families removed as serious fuel supply, there are left two great families, kerosene and fuel oil, to be considered. Of the latter, one-third to one-half is now consumed by the railroads in their oil-burning locomotives, and a large percentage of the remainder is used in heating operations, for which this oil is peculiarly well adapted. For power there remains the balance of the fuel oil family, nearly the whole of the kerosene family and a portion of the naphtha family.

With the increasing production of oil and the decreasing use of lamps, the kerosene used for light is becoming a small proportion of the total, and from the various sources enumerated fully one-half of our present total supply of fuel oil is available for power purposes in a properly designed internal-combustion engine. It is evident, then, that for the present the kerosene and closely allied families must supply the demand for oil power which the gasoline engine has created. It is further evident that this demand is so great that it will control the systems of refining and of distribution, and that in the near future a new family will spring up, combining kerosene and portions of these other families, which combination may be known as the power family. This will be the power-oil of the immediate future. The great refiners of this country realize this state of affairs and are preparing to meet it. They look forward to a day in the immediate future when a half, or more than a half of the oil supply of the country will be marketed for one purpose and under one trade name, and when power oil in tins or in tanks will be available in every hamlet, distributed in bulk to a myriad of distribution centres, and sold at a low cost; a low cost which is due to an efficiency in manufacture and transportation that has made the Standard Oil Co. the wonder of the world, for, whether or no this company was guilty of all or any of the sins laid at its door, it cannot be questioned that its skill and far-sighted wisdom in the manufacture and distribution of this product stand unrivaled in the world's history, and has given the public oil for various uses at cheaper and more uniform cost than is to be found in any other product.

For numerous reasons the various grades of kerosene have been extremely difficult to handle in an internal-combustion engine, and especially difficult to handle in that type of engine to which gasoline has educated the public and which in consequence the public insistently demands. Less volatile than its neighbors of the naphtha family, it cannot be vaporized in a carburetor of ordinary construction, and when vaporized it must be apparent that a very delicate adjustment of air to gas is necessary if a deposition of carbon on the cylinder walls is to be prevented. Properly handled, however, it burns with an exhaust that is absolutely smokeless at all loads or with any variation in load, and a gallon of what may be called low-grade kerosene or

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power distillate, contains more heat units and will deliver more power than its higher priced neighbors of the naphtha family. Two broad systems of using power oils of this grade have been developed, one a system in which the gasification of oil is dependent on heat, the other a system in which oil is gasified cold, exactly as gasoline is gasified. The former is older, but has never been wholly satisfactory, due to the impossibility of controlling the temperatures at various loads in any permanent and reliable manner, with the consequence that the cold carburetor system, controlled by the Secor-Higgins system of patents, has become the standard if not the only successful system for the use of the grade of oil in internal-combustion engines suited in any way to variable load.

The economies attained with this system are remarkable not only in themselves, but also for the wide range through which they are obtained. The economy curve of a kerosene gas engine with a Secor-Higgins system of carburetion is what engineers know as a 'flat top curve,' one in which there is uniformly high economy over a wide range of load. For example, on loads ranging from quarter-load to overload, an average in excess of 10 b.hp. per gallon of oil is uniformly secured, and it will never occur in any load between a third-load and a maximum overload that less than this figure will be obtained, while at best load (which is a load in the neighborhood of 20% less than the maximum) 11 to 12 b.hp. per hour will be obtained per gallon of standard kerosene. In Milwaukee at the present moment, kerosene of this grade, in quantities, is worth, in round numbers, 4½c. per gallon, delivered, making an average fuel cost on any load from quarter-load to full overload of less than one-half cent per horse-power hour, or less than three-quarters of one cent per kilowatt-hour, and at best load giving a horse-power for approximately four-tenths of a cent, and a kilowatt-hour for less than six-tenths of a cent. When it is remembered that there is no stand-by loss, and that this power is generated in a carefully designed, substantially built engine, requiring less attention than any previously known prime mover of equal power, one begins to realize the opportunity which power-users have before them and why it is that this is becoming pre-eminently the age of oil power and internal combustion engines.

HORSES WORKING THEMSELVES OUT OF A JOB BY AIDING OIL PRODUCTION.

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New Method of Rotary Well Drilling

By A. T. PARSONS*

OIL WELLS in California, and for that matter in the United States in general, are nearly always drilled either with the 'standard' or 'cable' tools, or with a 'rotary.' Drilling by standard tools consists of alternately raising by a cable and dropping a bit with a cutting edge, the action being practically the same as a churn-drill. At intervals the bit is raised and the hole bailed out. A log of the formations passed through is kept by examining the contents of the bailer. The formations in the California fields will not 'stand up,' and wells must be cased throughout. After a few hundred feet of casing has been used, friction becomes so great that it is difficult to force the casing any farther. 'Working' casing consists of pulling it back a short distance and then trying to force it ahead, and this process takes up a large part of the time in drilling a deep well. When the casing has in this way been finally advanced sufficiently, it will usually be found that considerable material has caved into the hole, which takes more time for cleaning out.

The circulator or 'slusher' is now often used as an adjunct to the 'cable' tools. This consists substantially in forcing water down through the casing to the bottom of the hole, whence it rises on the outside of the casing to the surface, carrying with it the mud churned up at the bottom of the hole. That is, it is supposed to carry the mud, and does so very well when the end of the casing is within a few feet of the bit. As a joint of casing is about 20 ft. long, however, it will readily be seen that the bit must sometimes be considerably over 20 ft. ahead of the casing, and under these conditions, results are not so satisfactory.

The water rising along the casing is expected to maintain a clearance between the walls of the hole and the casing and thus keep the casing 'free,' but occasionally the water will find its way up at one point only in the diameter of the hole and the casing found to be quite as badly 'frozen' as if no circulation were used. To the excellent article on 'Rotary Well Drilling' appearing in the June number of *Western Engineering*, I have nothing to add, except to reiterate that the rotary has few faults in a very soft formation, except the impossibility of keeping an accurate 'log' of the various strata passed through, but that in a hard formation or in boulders progress is slow, crooked holes are common, and much time is taken up in pulling drill-pipe to change rotary bits. In fact, none of the present methods of deep-well drilling are really satisfactory. A new system of well drilling has been devised, for which patent has been applied, by J. C. Barrett, of Taft, and me, which is intended to obviate many of

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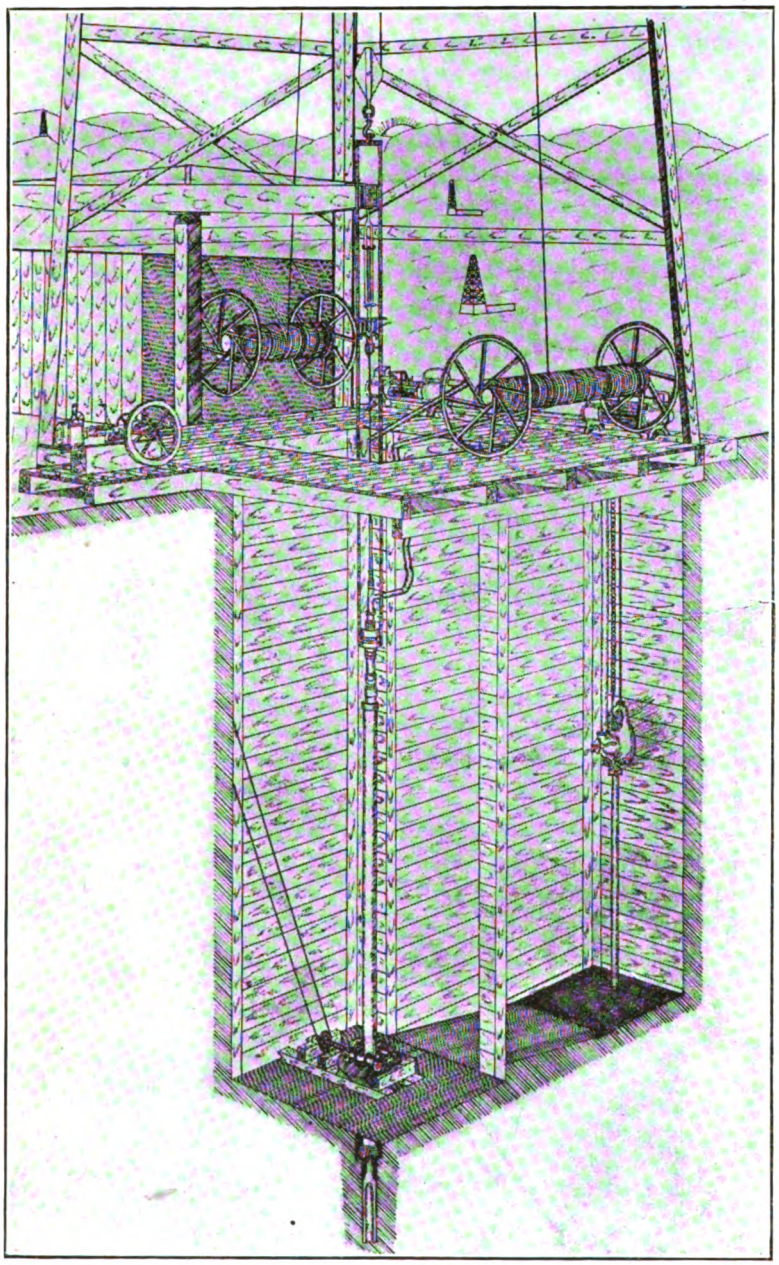

ARRANGEMENT OF PARSONS METHOD OF ROTARY WELL DRILLING.

the difficulties discussed above. A description of its operation is as follows.

A standard drilling rig is erected and equipped and a cellar about 10 ft. square and 20 ft. deep dug below the derrick. In this cellar is placed a rotary table driven by an engine at the surface. Drilling is done with standard tools, the drilling line going through the swivel, and at the same time the

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casing is kept free and advancing by continually rotating. The casing is fitted with a special saw-tooth shoe whose teeth terminate in grooves, assisting the circulator. This shoe will act as an under-reamer in all ordinary formations. A regular under-reamer should be used for going through a hard shell. The shoe is made to ream a hole considerably larger than the casing, and under ordinary conditions can follow the bit within six or eight feet. The swivel hangs by wire ropes from a block above the walking-beam. A tee in the swivel connects with the circulating pumps, the arrangement of the circulating system in general being the same as in rotary drilling except that the circulating water is either drained from the cellar to a sump and from there pumped to the surface, or else pumped direct from the cellar, in either case by an auxiliary pump. When the casing has advanced sufficiently to permit of adding another joint, the swivel is unscrewed, the tools raised from the hole, a joint of casing added, the swivel and tools returned, and drilling resumed. Under ordinary conditions this should be the only time when the tools are not actually at work at the bottom of the hole.

While bailing is unnecessary with this system, a sample of the formation may be obtained whenever desired with but little loss of time, by letting the bit get a little in advance of the casing, and running in a bailer in the usual way. While this method has not yet been actually tried out, it should not be regarded as an experiment, but rather as a combination or adaptation of the method already in use. The drawbacks of the cable tools alone, or cable tools with a circulator as discussed above, are eliminated, while the main advantages of rotary drilling are obtained without the well known disadvantages. The slightly greater cost of plant renders this system inadvisable for shallow wells, and it is doubtful whether there would be any material saving over the cable-tools in the case of a 1000 or 1200-ft. hole. There are also a few fields where, on account of the extremely soft formation, there is nothing to beat the rotary. With these exceptions, the system under discussion should give much better results in the oilfields than any system now in use.

SANDSTONE, ILLUSTRATING MATERIAL DRILLED IN THE CALIFORNIA OILFIELDS.

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North Pacific Coast Jetty Construction

By MYRON H. PECK*

IMPROVEMENTS of the bar entrance to Humboldt bay, the Columbia river, and Grays harbor are similar in general design. Each consists of a pair of jetties, though single jetties on the south side of the entrance were originally planned. As the prevalent winds of the stormy season are from the southwest, this appears to be an argument against the permanent efficiency of single windward jetties, but the present paper will deal only with methods of construction. Owing to the very heavy seas to which the North Pacific coast is exposed, jetties have hitherto been built by dumping rubble from pile trestles. During the severe winter storms, waves have been seen breaking in 95 ft. of water at Grays harbor. The summer winds are usually less violent and of shorter duration, and wave action correspondingly lighter. The accepted practice in jetty construction now is to commence the construction of a pile trestle on the line of the jetty as soon as the worst storms of winter are over. The trestle is carried only as far seaward as the current season's enrockment is expected to extend, allowing a sufficient apron at the scar-end to prevent scour during the winter months. A blanket layer of three to five feet of small rock, or brush mattresses weighted by small rock, follows the outer end of the trestle as closely as possible. The main enrockment, carried usually to high-tide level, is kept far enough behind the trestlehead to avoid causing excessive scour. This distance varies from a few hundred to two thousand feet. Details vary, as will be shown later when describing the work being done at the Columbia river and Grays harbor, but the only departure from this standard form of construction is now being tried at Humboldt harbor.

Humboldt Harbor Jetty

In 1899 the north and south jetties had been completed, the former to a length of 8000 ft. anad the latter 7400 ft., and both high-water level. A depth of 28 ft. on the bar was obtained soon after their completion, but this has decreased to 18 ft., coincident with the lowering in height of the jetties by wave action. The present project provided for bringing both levees up to high-tide level for their full length, with a top width of 20 ft. The pile trestle used in the original construction disappeared years ago, and experience has proved the difficulty, delay, and consequent expense of building a pile trestle over a rubble jetty. The plan adopted is to carry the jetty out from shore at a height of several feet above high-water, the rock being placed by a traveling crane running on top of the jetty, and brought to the crane on standard-gauge cars, also running on the jetty. The crane is shown in Fig.

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1, building the root of the jetty, above high water. The method is not altogether new, of course, but its use in so exposed a situation as the entrance to Humboldt bay is certainly bold. Trouble is anticipated by those in charge, and the cost of operation is estimated accordingly, but it is not thought that there will be any unsurmountable difficulties, and the saving in plant is very large. The rock contract calls for the delivery of 1000 tons per day, which

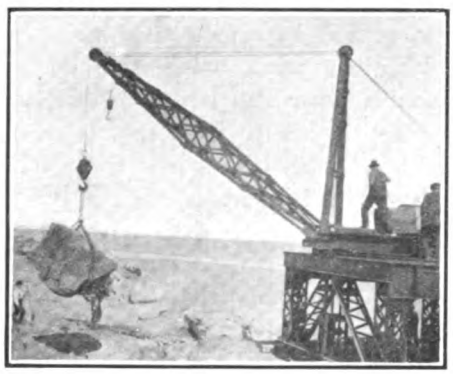

FIG. 1. CONSTRUCTING HUMBOLDT HARBOR JETTY.

will require working the cranes two shifts per day. Working in a very leisurely way, the crane has handled 60 tons per hour, of mixed large and small rock, the latter in skips. The Government engineers plan to have a large number of cars, so that when rock cannot be placed on the jetty, the loaded cars can be parked. Rock is quarried on Jacoby creek, hauled 8 miles to the bay, the cars loaded on a barge, 8 cars making a load, towed 12 miles, and delivered to the Government at a slip in the bay, about a mile from the root of the jetty. The crane track is 14-ft. gauge, and the standard-gauge rock-tracks will be laid inside these rails. A single track will be laid to a point near the scar-head, beyond which a double track will allow switching. Four-car trains will be run on the jetty. The train track is to be laid on and ballasted with a 2-ft. slab of concrete. A concrete mixer with engine and boiler and storage room for cement, is mounted on a flat-car and housed in. The crane is not very well adapted to the work, as it has a capacity of only 10 tons and was built for the concrete breakwater at Duluth. The storehouses, carpenter, machine, and blacksmith shops are compactly arranged between the landing slip and the jetty root, with an office and the bunk-house near by. Oil is used for fuel, except in the heating stove in the lounging-room of the bunk-house. It was originally used there also, but there was too much tampering with the valves. Fuel oil is pumped by the supply boat from the landing slip to a large tank near by, from which it flows by gravity to tanks at the shops, which contain a two days supply, and to the bunk-house kitchen. Water is obtained from a shallow well in the sand-spit, and pumped to a tank by a windmill.

COLUMBIA RIVER JETTY

The jetty at the mouth of the Columbia river is by far the largest undertaking of its kind on the Pacific coast, and extends 7 miles from the root at Fort Stevens. The original project, calling for a jetty 4½ miles long, was adopted in 1884, and in 1909 work was commenced on the extension, which will be completed this year. Preliminary work on the north jetty will also be commenced this season, and a part of the plant moved over. It was found in the earlier work that rock in place in the jetty weighed 107 lb. to the cubic foot, including voids, and that the stable side-slopes were about 2 on 3. Mattresses were used in the earlier work, but their use has been abandoned, as it is considered that they do not pre-

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vent scour, and cause unnecessary expense and delay. The jetty has been formed by dumping from a double-track trestle, as already briefly described.

The trestle is of the most substantial type in use for jetty construction and is 28 ft. above mean low water. The bents are 18 ft., centre to centre, each bent consisting of four piles, capped by a 12 by 16-in. timber, and tied together with eight 3 by 12 in. by 28-ft. diagonals. The stringers are double, each of the four consisting of one 12 by 16 in. by 36-ft., and one 8 by 16 in. by 36-ft. timber, breaking joints, and drift-bolted together. The larger timber is screw-bolted, and the smaller drift-bolted to the cap. The timbers are paired in the outside stringers, the inner stringers breaking joints with them; 5 by 6 in. by 5 ft. 6-in. ties, 12 in. centre to centre, are boat-spiked to the stringers. The track is 40-lb. rail, 3-ft. gauge, 13 ft. centre to centre of tracks. The caps are drift-bolted and strapped to the piles. The best strap is a piece of old wire cable, wound around the pile-head and over the cap, and fastened with railroad spikes to cap and pile. With this construction, and loaded trains alternating tracks daily, there has been no trouble with creeping of rails and stringers, as there was on the earlier work, and is now on the lighter trestle at Grays harbor. The piles are jetted down to a penetration of about 30 ft., by a turn-table pile-driver, mounted on a truck spanning both tracks. The driver is shown in Fig. 2, salving a rock train which ran off the trestle.

The rolling stock includes 15 locomotives and about 200 side-dump cars, of the type shown in Fig. 3. These cars were first designed for use at Coos bay, and are also used at Grays harbor. They are most satisfactory, being durable, easy to dump, and exceptionally stable on the track. Fig. 4 shows a rock train being dumped. During the season of 1911, 700,00 tons of rock was placed,

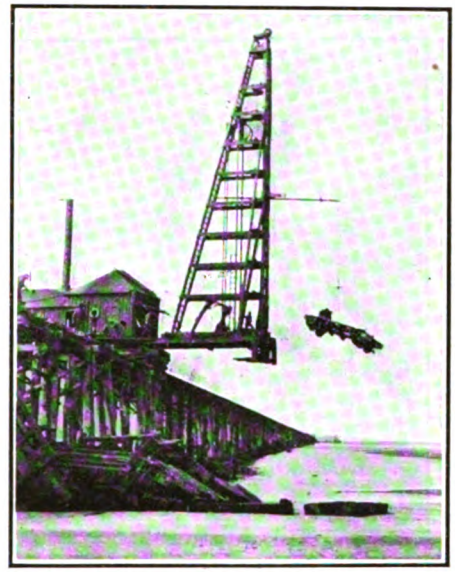

FIG. 2. SALVING ROCK TRAIN, COLUMBIA RIVER JETTY.

the average haul from the landing dock being about 6½ miles. Trains of 16 cars were run on an average headway of 11 minutes. Rock was weighed on track-scales holding two cars, and with a dumping crew of 5 men, 3 min-

FIG. 3. DUMP-CARS. COLUMBIA RIVER JETTY.

utes was required to clear a train. Telephone booths are placed at intervals of one-half to one mile on the trestle, and during foggy weather the trains are governed by a block system. A

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switch is placed in each block. The whole trestle is inspected twice during the night and constantly during the day. The rock is brought from a quarry higher for large rock than for small, which is loaded by hand on the skips which form the decks of the dump-cars. Fig. 5 shows a barge load of hard rock

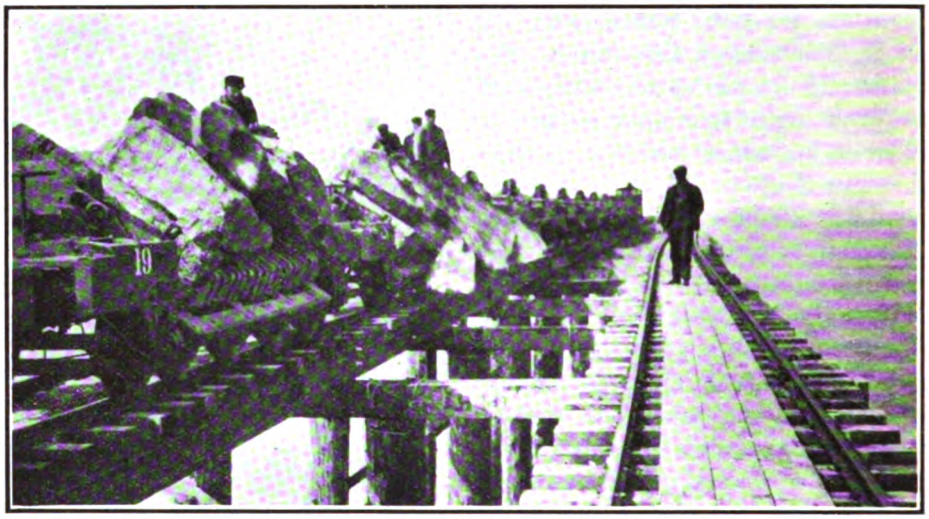

FIG. 4. DUMPING A ROCK TRAIN. COLUMBIA RIVER JETTY.

FIG. 5. UNLOADING ROCK FROM BARGE. COLUMBIA RIVER JETTY.

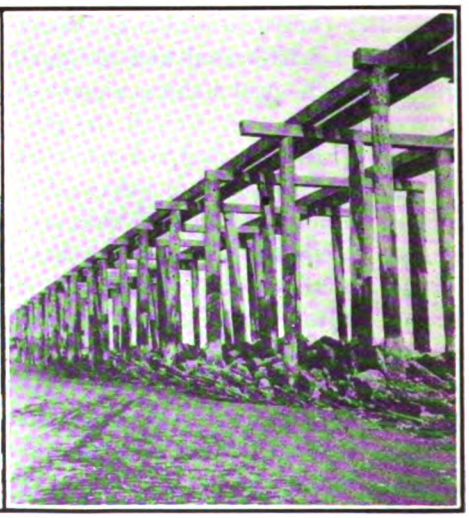

FIG. 6. JETTY ON MATTRESS. GRAYS HARBOR.

on the Columbia river, above Vancouver, on deck barges. The barges are unloaded at the landing-dock by stiff-leg derricks, a good days work being at the rate of 78 tons per derrick-hour. The rate varies greatly, being much being unloaded at the most efficient dock, there being 9 derricks in all.

It has been found that the winter storms usually destroy all trestles not protected by enrockment reaching at least to mid-tide level, and trestle work

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beyond such enrockment is pulled up at the end of the summer season. Here, as at Grays harbor, much trouble has been caused by the teredo and other marine borers. Various forms of protection have been experimented with, but none found satisfactory. Creosoted piles withstood the borers, but were found too weak for the lengths required. Green piles are used, and last several years where protected by enrockment.

Grays Harbor

The method of construction at Grays harbor is similar to that at the mouth of the Columbia, except that mattresses are used for foundation, and that the trestle is much lighter. The original project, adopted in 1896, provided for a single jetty 3½ miles long from a point on the south side of the harbor mouth. Of this jetty, 13,734 ft. was built by September 2, 1902, when work was stopped. In 1907 Congress provided for a jetty 9000 ft. long on the north side of the harbor entrance, and in 1910 added 7000 ft., bringing the end about opposite the end of the south jetty. Work was commenced in 1907 and the trestle completed for a length of 10,000 ft. by June 12, 1909. The mattress foundation for the jetty was placed for a distance of 7824 ft. The trestle consists of bents placed 16-ft. centres, each bent containing four piles, each pair of piles placed 5-ft. centres and 15 ft. between centres of pairs. Piles are jetted to 15 or 20 ft. penetration, the pile-driver used being similar to that at the Columbia. A 12 by 12 in. by 24-ft. cap is drift-bolted to the piles, and further fastened by an iron strap to the outside piles. Stringers 12 by 14 in. by 32 ft. under each rail 3-ft. gauge of track are fastened to caps by drift-bolts and ⅜ by 3-in. iron straps. Rails of 40-lb. weight per yard are spiked to the stringers, short lengths being placed at intervals of 400 to 500 ft., to be taken up and cut off when the creeping is bad. In spite of running loaded trains on each track on alternate days, the ends of stringers are sometimes separated two or three inches.

The engineer in charge is of the opinion that it is much better to lay rails on stringers than to use ties. He states that he has had a number of cars off the rails, but none off the trestle, while two or more trains have run off the Columbia river trestle, where car ties are used. The wheel flanges of a car jumping the track are held either by the grain or by the edge of the stringer, some cars having run several hundred feet in this way, while if the wheels run over ties the car is sure to be deflected and will either pull the train apart, or take it all overboard. The rolling stock is similar to that used at Columbia, but as an average of only 550 tons per day was placed in 1911, there is not so much of it. Trains of 12 cars were run, and the best day's work was 12 or 14 trainloads, with an average haul of three miles. A train crew consisted of an engineer and one brakeman, the engineer doing the firing and the brakeman dumping the train. The average time for a round trip is given as about 40 minutes, which means an average speed of nearly 12 miles per hour. This is pretty fast, considering that the track is crooked, and that at its outer end the trestle will swing through an arc of nearly two feet where there is a moderate swell. There was such a swell when I rode out to the end of the trestle, and I have much sympathy with the locomotive engineer, who, seeing the pile-driver equipped with a lifeboat and the engine with life preservers, refused to 'go to sea on a locomotive.'

The rock is brought 70 miles by rail,

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from Tenino to South Aberdeen, where it is loaded on barges and towed 17½ miles to the landing slip near the root of the north jetty. Two derricks handled an average of 550 tons, and a maximum of 746 tons per day from flat-car to barge. The average work done by the derricks at the Government landing slip during three months of 1911 was 40 tons per derrick-hour. Delays due to car shortage are included, but none due to delays of barges. The rock was not sorted, and consisted of about 50% of 4 to 10-ton pieces, 35% of 1000 lb. to 4-ton pieces, and 15% of 50 to 1000-lb. pieces. When barges contained large rock only, 60 tons and more per derrick-hour could be handled. Mattresses are built about 4 ft. thick, 30 ft. wide, and 32 ft. (two bents) long. Fascines are 9 to 14 in. diam. and 20 ft. long. They are wrapped with rope-yarn or lath-twine every 4 ft. They are built under the trestle, lowered to the water, and sunk by dumping four carloads of small rock on them. Considerable trouble is caused by the mattresses catching on the piles while being lowered. If a mattress is hung up within reach of the waves it is sure to be broken up. They have to be watched carefully to see that they are sufficiently weighted; at least 2 tons per linear foot of trestle is required to hold the apron beyond the enrockment through the winter. During 1911 a crew of 9 men, including the foreman, built 64 linear feet (4 bents) in 8 hours. The cost per cubic yard in place is at least 40% higher than that of rock, but the engineer in charge is certain that the use of mattresses is economical up to a depth of 20 ft., and thinks that for greater depths it is questionable. A jetty built in 20 to 28 ft. of water settled from 2 to 8 ft. in the first season, and as the side-slopes from edge of sand to top of rock remained at 1 to 1, this must have been due to scour under the mattresses. But as the engineer in charge has had ten years experience in jetty building, and his opinion is based on comparative experiments as well as experience, there must be some virtue in mattresses, though their use has been abandoned elsewhere. Fig. 6 shows a part of the trestle where the sand spit has been built up along the jetty, although only enough rock was placed to hold the mattresses.

Comparisons

Both at Grays harbor and at the Columbia considerable trouble and expense were caused by scour at the free end of the trestle, before mattresses or blanket layer of rock could be placed. At the Columbia, the bottom was sometimes lowered as much as 8 ft. in 24 hours, and at Grays harbor it was found impossible to cross a swash channel by working single shifts. The far bank was cut away ahead of the trestle-work, and could not be climbed until two shifts were put on and the work rushed at the highest possible speed.

There are two points on which more complete data than could be obtained would be valuable. The only reliable data obtainable on side slopes gave about 1 to 1 from sand to top, in depth up to 28 ft. at Grays harbor. Data on the number of tons per linear foot of jetty of different heights, with top width, depth of water when blanket layer was placed, and density of rock, would give some information about the percentage of voids if the side slopes were known. There is a great deal of data about the stable slopes of loose rubble under wave action, but accurate data on the percentage of voids in rubble mounds formed by dumping in water would be valuable in estimating on new work.

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Proportions of Storage Tanks

By E. R. COX

IN working out equations for the ratio of diameter to height which will give the least weight of tank for each capacity, certain assumptions are necessary which are in accordance with common practice in tank building. However, only three are vital to the mathematics involved; the rest may be inserted as constants in the equations derived, depending upon the judgment of the designer and the necessities of each case. For instance, the factor of safety is a very elastic quantity and varies widely in practice. Yet there is no good reason why it should not be constant for each tank, since the latter is only as strong as its weakest course. The thickness of roof depends mainly upon the possibility of snow loads, while that of the bottom is determined by the chances of corrosion due to soil, moisture, and whether the foundation is of concrete, asphaltum, oiled earth, or natural soil. The three assumptions which are vital to the calculations are: (1) that a minimum thickness of side is chosen, which shall extend down to a depth where greater thickness is required to withstand the pressure; (2) that below this depth the factor of safety shall be uniform; (3) that the top, bottom, and supports may be expressed as a constant weight per square foot for each range of capacities. Admitting these assumptions, the weight of a tank would be derived as follows: **D** = diam. in ft. **H** = height in ft. **P** = pressure in lb. per cu. ft. **t** = thickness of shell in inches. **w** = weight of plates in lb. per sq. ft. **f** = allowable working stress in steel. **E** = efficiency of joints as a fraction. **T** = minimum thickness of sides. **h** = depth below top at which **T** is required to withstand pressure.

$$\text{then } p = Hd. \quad t = \frac{DHd}{24fE}$$

$$w = 40.8t = \frac{1.7DHd}{fE}$$

$$\text{when } t = T, \quad 40.8T = \frac{1.7DHd}{fE}$$

$$\text{or } h = \frac{24TfE}{Dd}$$

Total weight of side to depth

$$h = \pi Dh \times 40.8T = \frac{3076T^2fE}{d}$$

$$\text{mean } w \text{ for } H-h = \tfrac{1}{2}\left(40.8T + \frac{1.7DHd}{fE}\right)$$

$$\text{Total wgt for } H-h = 1.571D(H-h)\left(40.8T + \frac{1.7DHd}{fE}\right)$$

$$= \frac{2.67dD^2H^2}{fE} - \frac{1538T^2fE}{d}$$

$$\text{let } a = \frac{2.67d}{fE} \text{ and } b = \frac{1538T^2fE}{d}$$

let R = wgt per sq ft. for roof, bottom, and support

$$\text{let } r = \frac{\pi}{4}R$$

then total wgt of roof, bottom and supports = rD^2. Call total wgt of tank W

$$W = aD^2H^2 - b + 2b + rD^2$$

$$= aD^2H^2 + rD^2 + b \qquad (1.)$$

let C = capacity of tank in bbls (42 gallons)

$$x = \frac{D}{H}, \quad e = \frac{\pi}{4} \times \frac{1728}{231 \times 42} = .1399$$

$$\text{then } C = eD^2H = ex^2H^3 \qquad (2)$$

$$\text{or } H = C^{1/3}e^{-1/3}x^{-2/3}, \quad D = C^{1/3}e^{-1/3}x^{1/3}$$

$$\text{and } W = ae^{-2/3}C^{2/3}x^{-2/3} + re^{-2/3}C^{2/3}x^{2/3} + b \qquad (3)$$

For the ratio of diameter to height giving the maximum weight of tank for a given capacity, the first differential coefficient of **W** with respect to **x**, considering **C** to be constant, would be equal to zero.

$$\frac{dW}{dx} = -\tfrac{2}{3}ae^{-2/3}C^{2/3}x^{-5/3} + \tfrac{2}{3}re^{-2/3}C^{2/3}x^{-1/3} = 0$$

$$\text{from which } x = a^{3/4}r^{-3/4}C^{1/2}e^{-1/2} = \sqrt[4]{\left(\frac{a}{r}\right)^3}\sqrt{\frac{C}{r}} \qquad (4)$$

substituting for C and x from (2)

$$H = \sqrt{\frac{E}{a}} = \sqrt{\frac{RfE}{3.42}} \quad \text{a constant.} \qquad (5)$$

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This is only true when $\mathbf{t} = \frac{\mathbf{DHd}}{\mathbf{24\ fE}}$ is equal to or greater than **T**. For capacities less than this, $\mathbf{t} = \mathbf{T}$ throughout.

Here $W' = 408\,T\pi DH + \frac{\pi}{4} D^2 R$ (6)

$= 128\,TC^{2/3} a^{-2/3} x^{-1/3} + \frac{\pi}{4} RC^{2/3} a^{-2/3} x^{2/3}$ (7)

$\frac{dW'}{dx} = -\frac{1}{3} \times 128\,TC^{2/3} a^{-2/3} x^{-4/3} + \frac{2}{3} \frac{\pi}{4} RC^{2/3} a^{-2/3} x^{-1/3} = 0$

or $x = \frac{81.6\,T}{R}$ a constant (8)

Accordingly, we find that above a certain capacity the most economical height is constant, below this capacity the most economical ratio of diameter to height is constant, and at this critical capacity both equations (5) and (8) are true.

Substituting constants which are in common use for large oil-storage tanks, $\mathbf{f} = \frac{55{,}000}{3}$, $\mathbf{E} = 0.70$, $\mathbf{d} = 60$, $\mathbf{T} = 3/16$ in., **R** depends upon type of tank.

For conical steel roofs, No. 12 U. S. gauge ..... $\mathbf{w} = 4.46$
For bottom No. 6 rectangular sheets about 75% and No. 4 sketch sheets ..... $\mathbf{w} = 8.60$
For supports (mean of four actual designs) ..... $\mathbf{w} = 3.69$
Total ..... $\mathbf{R} = 16.75$

For water top roof No. 10 U. S. gauge ..... $\mathbf{w} = 5.74$
For bottom, 3/16 in. ..... $\mathbf{w} = 7.65$
For supports ..... $\mathbf{w} = 4.01$
Total ..... $\mathbf{R} = 17.40$

For wood roof at \$13 per square, steel at \$0.05 per lb. erected, the equivalent weight of plate would be. 2.6
Bottom 8.6
Total ..... $\mathbf{R} = 11.2$

For open tank ..... $\mathbf{R} = 8.6$

$a = \frac{2.67\,d}{fE} = .0125$

$b = \frac{1538\,T^2 fE}{d} = 11500$

$H = \sqrt{\frac{Rf E}{3.4 d}} = \sqrt{62.8\,R}$

$x = \frac{81.6\,T}{R} = \frac{15.3}{R}$

$\mathbf{C'}$ = critical capacity. $\mathbf{D'}$ = corresponding diam. **D** = greater diameters than $\mathbf{D'}$. $\mathbf{D''}$ = lesser diameter than $\mathbf{D'}$.

Type	R	H	x	D'	C'	D''
Conical steel roofs	16.75	32.4	92	29.8	4000	$1.87\sqrt[3]{C}$
Water top roofs	17.40	33.1	876	29.	3900	$1.84\sqrt[3]{C}$
Wood roofs	11.20	26.6	1 36	36.	4820	$2.13\sqrt[3]{C}$
Open tanks	8.60	23.2	1. 77	41.	5450	$2.33\sqrt[3]{C}$

Substituting $x = \left(\frac{a}{r}\right)^{3/4} \left(\frac{C}{e}\right)^{1/2}$ in (3) gives

$W = \frac{2C}{e}\sqrt{ar} + b = 1.418\,C\sqrt{r} + 11500$

Substituting $x = \frac{81.6\,T}{R}$ in (7) gives

$W' = 536\,R^{1/3} C^{2/3}$

This gives a table which is convenient for approximate slide-rule estimation.

Type	R	W	W'
Conical steel roof	16.75	5.8C+11500	$137\,C^{2/3}$
Water top roof	17.40	5.91C+11500	$139\,C^{2/3}$
Wood roof	11.20	4.75C+11500	$120\,C^{2/3}$
Open tanks.	8.60	4.16C+11500	$110\,C^{2/3}$

To these weights should be added from 10 to 15% for laps, rivets, loss in shearing, and overweight.

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The Engineering Digest

Utilization of Fuel Oil on Donkey Engines*

By J. P. VAN ORSDEL

THE use of fuel oil on donkey engines has been of considerable interest to me for the past three years, not only from the point of a possible saving in fuel and labor cost in supplying the machines with energy, but from the point of conserving the timber and eliminating the fire risk, or at least reducing it to a minimum.

There is no other thing except the effort to make a profit that gives the logger and timber owner as many sleepless nights during the dry season of the year as the fire hazard. It is a constant menace which is always with us and impossible to get entirely away from, but I am sure that every lumberman is making a strenuous effort to as nearly eliminate this risk as is in human power to do. Eternal vigilance and fuel oil will come near to saving this enormous natural and national resource which means so much to the financial and industrial life of the states which are members of this Congress.

In the following discussion coal as fuel for donkey engines is not taken into consideration, due to the fact that I have had no experience with coal as fuel on this kind of machinery.

During the last six months of the year 1911, at our Gray's River camp, we made some experiments with an oil installation on one of our machines which was being used to scrape gravel from a bar to ballast cars. This machine was a 9 by 10 Willamette Iron & Steel Works donkey, equipped with a 60-in. boiler. The oil was supplied to the burners by gravity. Our idea was at first to put three burners of the Witt type in the firebox, giving the burner a slight tilt downward so that the flames from each burner would have a tendency to rise and swirl, and in that way filling the firebox full of well distributed heat energy. We were able to supply the machine with steam all right as long as the load was the same; in fact, it steamed a hundred per cent better than with wood fuel; but we found the installation to be a failure for the reason that it had to be fired with a throttle under the control of a fireman, which we found would be impractical on any machine which is subject to the wide variation in load and steam consumption that a logging engine is subjected to—no human hand or mind being capable of responding to fluctuations in steam pressure as it exists on a logging engine. As a result of our at-home experiments we decided that in order to utilize fuel oil on donkey engines successfully for logging purposes, it would be necessary to have an automatic oil-feed device which would increase or decrease the oil flow according to the steam pressure without the assistance of a fireman. It needed to be some device that would increase the oil flow as the steam pressure decreased, and when the steam pressure reached approximately or slightly under the blowing-off point it would cut the oil flow down so that you only had a slight fire, and in this way the waste of oil would be reduced to a minimum.

Of course, it was impossible to tell exactly the amount of oil we would have used on this machine had we been yarding logs with it. But our opinion was that it would require from eight to nine barrels per day, which has since been confirmed.

During the same time that we were mak-

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ing these oil tests I had men at the various camps keep records of the amount of wood used per day by yarders operating in yellow fir and using yellow fir for fuel; yarders operating in red fir and using red fir for fuel; and yarders operating in silver fir and hemlock and using silver fir and hemlock for fuel; and I find, as an average of these tests, that we were using for fuel 1650 ft. of timber per day.

Of course, the contention might be raised that we do not use merchantable timber for fuel, but where you are running the machines for all they are worth this is not so, especially with regard to red fir, silver fir, or hemlock. The best logs in the woods are used for fuel. Of course, in the yellow fir you can occasionally get a log that is shattered or full of pitch rings, or a log from a dead standing tree that is worm-eaten. Rotten or punky timber will not make steam, nor will a knotty log split. It takes good timber to make steam.

You all know that it costs more to put a wood log behind a yarder than it does to load it on a car and haul it to your mill or any other dumping ground. The hardest men in your camp to keep who render satisfactory service are your firemen and woodbuckers; or at least that has been our experience.

Figured on the following basis, it costs $18.13 per day to supply steam energy with wood fuel to a logging engine working under ordinary conditions.

Average daily wood consumption, 1650 ft. B.M.

Stumpage value of timber, $3 per M.

Straight logging cost, $4 per M.

Additional logging cost for wood logs, 50c. per M.

One fireman at $3 per day.

One wood-bucker at $2.75 per day.

If the above does not conform with your ideas of values, logging, cost, or wage scales, it will be a simple matter to convert them to conform with your ideas.

In the early part of 1912 Mr. Glafke, of the Loggers' Oil Equipment Co., brought to my attention an automatic oil-burner device which seemed to have just the features which we lacked in our experiments, so I gave him an order for two installations, which we began using in the early part of February and which from the very start gave good and satisfactory results. We have since added two more, making a total of four installations at our Gray's River camp. All installations have been made on a 66 by 120-in. Willamette Iron & Steel Works 200-lb. working pressure boilers. The following are our records, which have been kept with great care.

RECORD NO. 1

The machine was a 10 by 13 Mogul yarder, built by the Willamette Iron & Steel Works, equipped with a 66 by 120-in. 200-lb. working pressure boiler. We had the safety-valve set at 185 lb. In the months of February, March, April, May, and June this machine actually worked 104 days, and our records show that the average oil consumption was 9.6 bbl. per day. The ground this machine was yarding is very rough. The average log contained 1975 ft. scale. The maximum yarding distance was 1300 ft.; average, 650 ft. Average output per day during the 104 days the test was run was 80,500 ft. M per day. Cost of oil per barrel delivered in tank on rear end of donkey sled, $1.05, or a fuel cost of 13.7c. per M. Had we used wood fuel this cost would have appeared as 22.5c. per M, or a saving of 8.8c. per M, or a daily average saving of $7.08. The 104 days would show a total saving of $736.32.

RECORD NO. 2

The machine was an 11 by 13 Mogul yarder, built by the Willamette Iron & Steel Works, equipped with a 66 by 120-in., 200-lb. working pressure boiler. We had the safety-valve set at 175 lb. In the months of February, March, April, May, and June this machine actually worked 96 days, and our records show that the average daily oil consumption was 7.8 bbl. The ground this machine was yarding is extremely rough, it being necessary at times to use two lead blocks and a stump roller to get the timber out at all. The average log contained 1870 ft. M. The maximum yarding distance was 1500 ft., and the average 750. The average output during the 96 days the test was run was 59,400 ft. M per day. The cost of oil per barrel delivered in tank on rear of donkey sled, $1.05, or a fuel cost of 13.8c. per M. With wood fuel the cost would have been 30.5c. per M, or a saving of 16.7c. per thousand feet.

It may appear that the wood consumption would have been decreased, as the oil used was less than the amount used on machine

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covered by record No. 1. In this particular instance this machine was set in such a cramped place that it would have required an extra man back of this machine to keep it in steam with wood. It would have been impossible for us to have got the nearest end of the woodyard closer than 35 ft. from the fire-door.

RECORD No. 3

This is a test run on an 11 by 13-in. Willamette Iron & Steel Works Mogul tandem-drum yarder, equipped with a 66 by 120-in., 200-lb. working pressure boiler, carrying its full allowable working pressure. This machine was 29¼ working days logging all the timber tributary to one rollway. The total oil consumption during this period was 373 bbl., or 8.9 bbl. per day. Total amount of timber logged in this time, 2,886,816 ft., or an average daily output of 98,700 ft. Reducing this to a fuel cost per M, we have at $1.05 per barrel for oil delivered at the machine a cost of 9.5c. per M. The wood fuel cost per M would have been 18.4c., or a saving of 8.9c. per M or $8.78 per day. This would show a net profit on logging this setting of $256.89.

In talking over the performance of this machine with the camp foreman, hook-tender, and engineer, they were all of the opinion that the oil made it possible for them to get this output. The foreman said 75,000 ft. per day would have been all they could have done with wood. The maximum yarding distance was 1200 ft.; the average, 600. This was uphill yarding with a maximum lift of 325 feet.

In the latter part of June chief inspector Paddock of the Hartford Boiler Insurance Co. inspected these boilers very carefully, to see if the use of fuel oil was injuring them in any way, and his report was that they were in fine condition and should last just as long with fuel oil as with wood fuel.

In our Rainier camp we have three 10 by 11 Humboldt yarders, built by the Willamette Iron & Steel Works, equipped with 54-in. express boilers, the firebox being 54 by 78 in., which are the best wood steamers it has ever been my experience to see in operation. The Logging Oil Equipment Co. and the West Coast Oil Equipment Co. have both made installations on these machines without any success. But as we needed the logs we could not afford to let them take the time to experiment and correct errors in installation. I have not the least doubt that either one could have worked it out satisfactorily. We expect to give them another opportunity to do so during the shut-down period this winter. We have not been very successful so far with small upright boilers—of, say, 54-in. diameter—for logging service.

There is no doubt that we all have a great deal to learn about the use of fuel oil—not only the people who are making the installation, but those of us who are using it. My experience so far has been that it is more a question of time. As far as the money is concerned, there is a very apparent saving with it from the start.

In conclusion, I will say that in comparing wood fuel with fuel oil on donkeys, the oil has the following advantages over wood: (1) It conserves the forests; (2) reduces the fire risk to a minimum; (3) increases the possible output from 15 to 25%; (4) reduces the logging cost materially in that it decreases the fuel cost and increases the possible output.

Electric Logging*

By JAMES R. THOMPSON†

THIS is a subject which must be divided into two parts, the engineering and the financial side of the subject.

So far the Potlatch Lumber Co. and the Smith-Powers Logging Co. are the only ones to take up logging with electric donkeys, and the results so far obtained are only preliminary to the determination of the designs and requirements that will be necessary. Each of the electric logging donkeys consists practically of an 11 by 13 Willamette yarding donkey, with 150 or 165-hp., 3-phase, 60-cycle

*Address delivered before Pacific Logging Congress, Portland, Oregon, July 1912.
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induction motor in place of the boiler and engine, and with air-actuated friction in place of steam, for which the compressed air is furnished by an electric driven compressor. The replacement of the twin 11 by 13-in. engine by a motor of 150 or 165 hp., even after making allowance for the overload capacity of the motor when operating in bad ground or heavy timber, without question points to the use of larger motors.

The steam-engines of an 11 by 13 donkey will probably indicate 600 hp. and are capable of exerting all the speeds practical and the same maximum pull on the hauling cable.

With the electric motors it is figured that they will be capable of exerting enough pull or torque at the start, when the torque or pull is maximum, to break any cable now in use, the amount of pull gradually decreasing until full speed of the motor is reached, when it will be between one-fourth and one-third of that at starting.

With heavy logging or bad ground this would necessitate the automatic slowing down of the electric motors and increasing the time required to haul the logs to the yard. Whereas, with the steam donkey, by control of the throttle, the engineer is capable of keeping up necessary or maximum pull on the cable at all speeds which the steam donkey is capable of.

The question of power factor also enters into the electric donkey very seriously, and the best way which I know to describe the power factor is that it is like a log that scales 1000 feet, logs clear both ends and outside, looks all right, but when you run it through the mill you have only 500 ft. of lumber that is marketable. In other words, with alternating current your quantity of amperes times the volts does not equal the product of their multiplication of units; or in other words, you are quite apt, under extreme cases, to have only 50% of the apparent horse-power that ampere meters and volt meters may indicate.

This in the first place will necessitate larger motors than the actual horse-power requirements on account of the heating, which will also affect the speed of the motors and the starting torque, and larger transmission lines to carry the amount of horse-power.

It will also have the effect, when several logging donkeys are operating from the same transmission circuit, of causing their speed and torque to change when one or more of the logging donkeys are started or stopped on this circuit, and in fact it really means an increased size of everything over the theoretical clear back to the electrical generator supplying the current.

It is generally admitted by engineers with whom I have talked on the subject of electric logging, that the power factor will be from 50 to 60%; and what is still more important is the load factor based on the rating capacity of the motor on the logging donkeys will not exceed 15%; or in other words, the amount of power in kilowatt-hours that your generator is capable of turning out in the time that you are doing actual hauling of logs and gear, will only be 15% of the total possible kilowatt-hours. This means that your generating stations are not to be worked to high efficiency of output.

The problem of moving the electric donkey has a great many details to be worked out, but will most likely resolve itself into the use of an extra set of step-down transformers, flexible cables, high-tension oil switches, so that the donkey may be moved several hundred feet, and then the step-down transformers, which are to be hauled along with the donkey, connected up, and the set that has been supplying the power through the flexible cables brought to the donkey and the moving started over again. This will require good switching stations, so that parts of the transmission line may be made dead. Thus linemen can make connections in any weather.

Protection against danger of electric shock will have to be considered very seriously, both in details of safety to the linemen in handling and working with high-tension circuits and the danger through grounding by reason of the breaking down or puncturing of the insulation of either the transformer or motor. This will require the most thorough grounding of the donkey to the earth to prevent the electric ground from being carried out on the cables to hook-tenders and other men handling the gear.

Thorough protection against lightning must be also made, not only from danger to men from this one source, but by reason of the danger of disability of the electrical apparatus, as it will have in the woods a tendency to act as a lightning arrester for the transmission lines.

From what I can learn concerning the

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operation of these electric logging donkeys, it cannot be said, owing to the electric current, or the generator stations from which they were furnished, that they have had a fair show.

I believe it is going to be the old case of the steam donkey over again, from the small 8 by 10-in. to the 14 by 14, as the requirements and economics of operation require. The electric donkey must be, like the steam donkey, able to do just as good work, if not a great deal better, and if there are any defects in it which cause a waste of labor by reason of delay or output, it is going to be a very serious defect. This has been shown in the gradual creeping up in the size of steam donkeys and the total abandonment of all blocking methods of taking logs out of the woods.

The advantages of the electric logging donkey may be summed up, as far as I have been able to learn, in the lessening of the fire risk, the saving by reason of requiring no fuel, which in some cases, I understand, is considerable on account of some of the best trees being used for fuel, and the cost of piping feed water for the steam donkey, which in some cases has to be piped and pumped considerable distances, at large expense, and the ability to use the electric donkey without reference to any water supply. The saving effected by these will be in each case different and individual, and can only be taken up as a special case. For instance, in some camps, oil or coal or slab wood is being used instead of cutting up trees in the woods, and it may be tnat in time some of the larger loggers will take the matter in hand as is done in many small individually operated camps and the best trees will not be used for fuel because they are easy splitting; also boilers of larger capacity will be, without doubt, installed, so that a great deal of refuse of the woods may be burned under them satisfactorily.

On the financial side of the question, I hardly believe, except in some extreme cases, any power company would care to have or seek the sale of power to a logging camp on account of the electrical disturbances created on its transmission lines by the starting and stopping of large motors, and the effect of both power and load factor, the latter being of the greatest importance to the power company. As it now stands, most power companies are selling on the basis of a stand-by charge plus a kilowatt-hour charge, and it is seldom that this stand-by charge is less than $1 per kilowatt per month of maximum demand with a 150-hp. motor on the logging donkey; this would involve a guarantee payment for each donkey of not less than $1800 per annum, plus the kilowatt-hour charge for the current consumed.

It may be possible, however, that large companies which have a large acreage, the logging of which is going to extend over a long series of years, may find it advisable and profitable to install the electrical donkey, especially when they are operating mills or factories within reach of their timber by transmission lines.

The expense of installing steam turbines to develop power for the donkeys will cost, in most cases, approximately $65 to $75 per kilowatt; or in other words, the investment in the generating plant for the logging donkey in the woods will be approximately $10,000, to which must be added the cost of transmission lines and other apparatus.

At this date I do not think anyone is in a position to state definitely just where electric logging is going to end. Each district has a different class of timber and different topography, and it is to be hoped that in some favorable locality an electric donkey may be placed to give it a chance to show what it may do without putting maximum conditions against it at the start.

One of these possibilities is in the sky-line method of logging used by the Potlatch Lumber Co., in which the logging donkey conforms more nearly to the duties of a large hoisting engine and in which, while the loads may vary greatly in weight, are free from all sudden jerks and impediments with which the present yarding method is afflicted.

It is my opinion that the electrical logging donkey will go through a very wide and extensive transformation, both in the size and type of motors and the method for the control of the same, and it is to be hoped that this transformation will be rapid.

Looking back at the electric trolley car, which started out years ago with a 7½-hp. motor, and the electric railway service, which now has motors totaling over 1000 hp., a great many years have elapsed. I hope that we will not have to wait more than a fraction of the time to pass before the development and evolution in electric logging will be an accomplished fact.

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Oil Well Compressed-Air Pumping Systems

By EDMUND M. IVENS

THEORY of the 'air-lift' or compressed-air pumping system has been extensively discussed, but there is comparatively little data in existence showing the actual performance that may be expected in the application of this method to pumping oil. Edmund M. Ivens conducted an extensive series of tests of compressed-air pumping systems in use at Evangeline, in the Louisiana oilfields, and presented the results of his findings before the meeting of the American Society of Mechanical Engineers, May 1909. We believe that his paper will be of particular interest to readers of *Western Engineering* engaged in the oil industry, and have, therefore, prepared the following abstract.—EDITOR.

EXPLANATION OF TERMS USED

'Submergence in feet' refers to the number of feet below the surface of the fluid (after the well has been pumped down, and is operating under its normal conditions) that the air under pressure is admitted.

'Per cent of submergence' is the submergence in feet divided by the total number of feet of vertical discharge line, measured from the point of admission of the air to the point of discharge of the fluid.

'Volumetric efficiency' of the compressor is the actual amount of free air that is compressed and discharged by the cylinder, divided by the cubical contents of that cylinder.

'Free air' is air at standard temperature and pressure.

'Pumping head' is the vertical distance in feet (after the well is pumped down, as before stated) from the fluid level in the well to the point of discharge.

$$\text{'The Constant'} = \frac{\text{Gal. per minute} \times \text{pumping head in feet}}{\text{Cu. ft. of free air per minute}}$$

$$\text{'The ratio'} = \frac{\text{Cu. ft. of free air per minute}}{\text{Cu. ft. of fluid per minute}}$$

Fig. 1, 2, 3, and 4 illustrate the air-lift systems that are and have been in use in the oilfields. Fig. 1 shows the 'straight air' or 'Sanders' systems. The well top is sealed as shown at *A*. Compressed air is forced through the pipe *B* into the space between the discharge or eduction pipe *C* and the well casing *D*. When without air pressure, the fluid in the well will stand at some point such as *E*, the level in the air space and the discharge line being identical. When air is forced through *B*, the level of the fluid

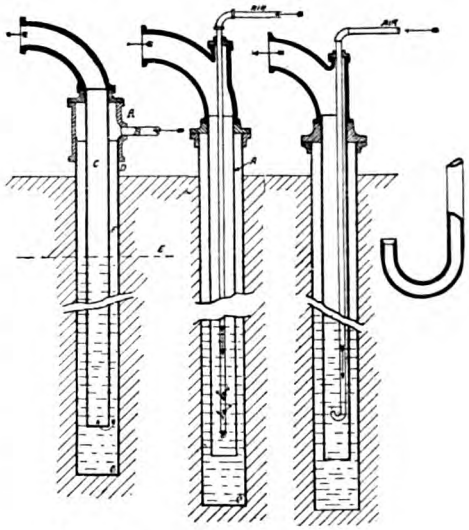

FIG. 1. STRAIGHT AIR-LIFT SYSTEM. FIG. 2. CENTRAL PIPE SYSTEM. FIG. 3. RETURN BEND SYSTEM.

in the air space is gradually forced down until the end of *C* is uncovered. Instantly some of the air escapes into the discharge pipe *C*, lowering the air pressure in the space *F*. This causes the fluid to rise in and up to the air space and discharge pipe until a point is reached where air and water pressure balance. Then, more air coming in, the pressure again rises, the fluid level is forced down as before, more air escapes into the discharge pipe, and thus the cycle is repeated. As may be readily seen, the air that rushes into the discharge line carries the 'slug' of water that has just previously entered.

Fig. 2 shows what is commonly known as the 'central pipe' system. The discharge line *A* is placed inside of the well casing as before, and inside of the discharge is

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suspended a small air-line usually 1¼ in. diameter. The end of the 1¼-in. line is plugged and a number of ⅛-in. holes are drilled inclining upward in the last joint of pipe. Air is forced down through the small air-line shown, passes out of the ⅛-in. holes, and mingles with the fluid carrying it out through the discharge line *A*. It is generally supposed that the fluid in this case is discharged because of the aeration of the fluid in the discharge pipe, which in turn is caused by the intimate commingling of air and fluid. The weight of the fluid column inside of the discharge pipe is therefore less in pounds per square inch than that without, and the energy due to this difference in weight is utilized to lift the fluid and overcome the various losses.

What is commonly known as the 'open-end' system of air-lift was at one time in quite extensive use in the field. It is similar to the system just described except that the small air-line is open at the lower end, and of course there are no holes drilled in the air-line. Fig. 3 illustrates a form of the 'return-bend' system. It is claimed by the inventor that: "It consists in improved processes and apparatus whereby the compressed air is delivered in bulk into the lower end of the water eduction pipe, and the water and air are caused to ascend through said pipe in distinct alternate layers of definite dimensions." The use of this system has been discontinued in Evangeline, because, as the field managers told me, it failed to produce as large a quantity of fluid as that produced by other systems.

Fig. 4 shows a patent system which in reality is a combination of the several systems already described. The claims of the inventor are: less submergence and hence less air-pressure necessary, decreased air consumption, or with an equal amount of air, increased fluid yield. Compressed air is forced through *a* down into the foot piece, which is placed at that point of submergence shown by test to be most economical. The well top is sealed and air under pressure is also admitted between the casing and discharge pipe on the water head by means of the branch shown at *b*. This forces the fluid to a higher level in the discharge pipe and also prevents fluid in the air-space or chamber from vibrating and foaming. This is quite an advantage in oil-well pumping, as the liability of making 'riley oil' is thereby greatly lessened. The footpiece shown in section is made of cast brass and is in two parts. The air on reaching the footpiece divides and goes up through the hollow prongs *f* and *g* and out the nozzle *n*. The

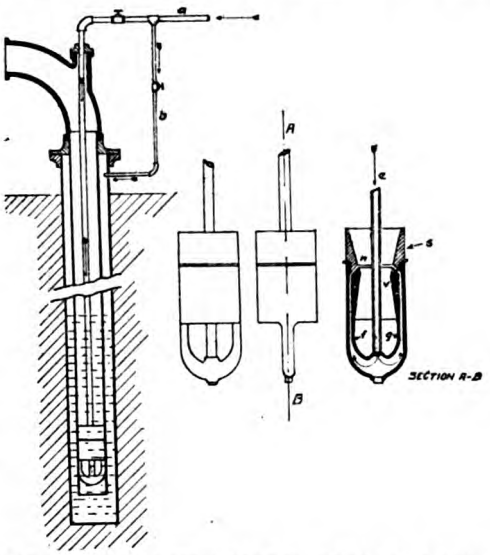

FIG. 4. SYSTEM COMBINING FEATURES OF OTHER SYSTEMS DESCRIBED.

nozzle is adjusted to receive the quantity of air to be used by screwing the upper part *s* of the footpiece in or out, as the case may be. To increase the velocity of the fluid in the discharge line, the footpiece is restricted and formed into a 'venturi' as shown at *v*.

The Crowley Oil & Mineral Co. was the first to take active steps for the improvement of its plant and pumping equipment. The company decided to install the patent air-lift last described (Fig. 4). A test of the old system was first made to determine the amount of compressed air used and the fluid yield. The new equipment was next installed and a similar test made of the same duration and under the same conditions. The tests and installation were conducted on well No. 32, 1805 ft. deep, and situated 542 ft. from the compressor operating it. The air to the well was controlled by means of a manifold in the plant and was conveyed to the well top through a 2-in. pipe-line which, as usual, was in poor condition and badly designed. The system of pumping was that illustrated in Fig. 1. The well casing was 6 in. diameter, sus-

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pended inside of which was a 4-in. discharge line. The compressor was a duplex steam and compound air type, made by the Ingersoll-Rand Co. and designed to compress 1000 cu. ft. of free air per minute to 350 lb. pressure. The steam end was fitted with Meyer adjustable cut-off valves, and the air end with Corliss intake and poppet discharge valves. The discharge pipe from the well top was run up into a steel tank of known dimensions, and the amount of fluid pumped during the test ascertained by direct measurement. Air gauges, previously tested, were placed both at the compressor and at the well top, thereby making it possible to determine the friction losses in the manifold air-line and also the actual pressure at the well top. Simultaneous indicator cards were taken from the steam and air ends of the compressor, and from these cards were obtained the volumetric and mechanical efficiencies, the steam and air horse-powers, and the steam consumption (theoretical) of the machine.

The volumetric efficiency was assumed to be the ratio of the piston travel during admission stroke to the total piston displacement. Sometimes this method is inaccurate and unsatisfactory: (1) because the entering air at atmospheric temperature and pressure is heated by contact with the cylinder walls and piston, and (2) because of leakage of air from the compression side of the moving piston to the suction side. Neither the expansion resulting from the first condition nor the reduction in volumetric efficiency resulting from the second are observable on the indicator card. The first inaccuracy was partly overcome by placing a recently calibrated thermometer as far down in the intake pipe of the compressor as possible, noting the temperature and making

TABLE 1. SUMMARY OF RESULTS

(The Crowley Oil & Mineral Co., Evangeline, Louisiana.)

	Old System.	New System.
Duration of test, hours	5.500	6.000
Mean i.h.p.	122.560	89.190
Mean water hp.	9.970	10.360
Mean air hp.	107.380	79.160
Gallons of fluid per second	0.542	0.608
Gallons of fluid per hour	1953.600	2188.200
Barrels of fluid per hour	46.510	51.100
Weight of 1 gal. of fluid	8.700	8.690
Mean temperature of fluid, deg. Fahr.	111.500	113.200
Percentage of salt water in fluid	87.300	86.700
Percentage of sand in fluid	2.200	1.900
Percentage of crude oil in fluid	10.500	11.400
Barrels of oil per hour	4.880	5.940
Barometer reading, inches of mercury	29.950	29.940
Specific gravity of oil	0.900	0.900
Constant	63.100	101.800
Size of air-line, inches	.....	1.250
Total depth of well, feet	1805.000	1805.000
Size of casing, inches	6.000	6.000
Height above ground to which the fluid was pumped, feet	18.500	18.500
Size of discharge line used, inches	0.400	0.400
Total length of vertical discharge line	1513.500	1513.500
Total length of vertical air line in well	1513.500	1493.000
Dimensions of compressors, inches	10x22x16x20	7½x18x16x20
Number operated	1	1
Kind of fuel used	Crude oil	Crude oil
Gallons of fuel used per hour	48.3600	35.2700
Barrels of fuel used per hour	1.1500	0.8350
Price of 1 bbl. of oil at time of test, dollars	0.9000	0.9000
Cost of fuel for producing 1 bbl. of fluid, dollars	0.0222	0.0146
Cost of fuel for producing 1 bbl. of crude oil, dollars	0.2120	0.1260

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the necessary corrections as will be observed in the log of results.

Every thirty minutes for a period of six hours, readings were taken of the boiler pressure gauge, the air gauge at the compressor and at the well top, the r.p.m. of the compressor, the temperature of the intake air and of the barometer. A set of indicator cards, and also a sample of the fluid pumped from the well, were taken at each interval. The temperature of each sample of fluid was noted; it was then placed in a proper receptacle, and at the end of the test the weight of a gallon was ascertained, together with the specific gravity of the oil. The amount of fluid pumped was determined, as before stated, by direct measurement, due allowance having been made for the samples that were withdrawn. When these tests were run, no attempt was made to redesign the air-lines, or to correct in any manner the numerous other defects. The old system was tested just as it had been operated, and the new system was installed and tested under the same adverse conditions. After both systems had been tested, some few of the defects were corrected in the manifold and air-line design, thereby insuring more economical operation in the future.

The saving in air volume accomplished by the new system led those interested to endeavor to operate two wells with one machine—something before considered impossible in the field. Well No. 30 was forthwith tested, though not with sufficient accuracy to warrant the publication of the results, and the approximate pumping head and submergence established. The new system was then installed with the requisite pipe to equalize the submergence (hence working pressure) of this well with that of No. 32. The two wells in question were then connected to one air-compressor with gratifying results. No trouble was experienced in starting, and the machine furnished air in abundance for steady operation. Preparations were being made to run the usual test when the compressor operating well No. 12 'went dead.' This last-named well had been previously tested and equipped with the new system. This shut-down, of course, would mean a loss of at least a day's production from the well, amounting to quite an item, so I advised that this well be also connected to the machine already operating No. 30 and No. 32. By speeding the machine up a few revolutions, the additional load was easily taken care of, as may be more fully noted by reference to the accompanying log (table 2).

TABLE 2. SUMMARY OF RESULTS

(Wells No. 12, 30, 32, Crowley Oil & Mineral Company)

Duration of tests, hours	6.00
Mean (total) i.h.p.	151.10
Mean (total) w.h.p.	25.14
Mean (total) a.h.p	129.05
Total gallons of fluid per hour	6168.00
Total barrels of fluid per hour	146.87
Total barrels of oil per hour	16.17
Well No. 12:	
Weight of 1 gal. of fluid	8.50
Temperature of fluid	118.50
Percentage of salt water in fluid	87.20
Percentage of sand in fluid	1.30
Percentage of crude oil in fluid	11.50
Barrels of oil per hour	6.44
Specific gravity of oil	0.87
Total depth of well in feet	1705.00
Size of casing, inches	6.00
Size of discharge line, inches	4.00
Well No. 30:	
Height above ground to which fluid was pumped, feet	17.50
Total length of vertical discharge line	1025.50
Total length of vertical air line	992.58
Weight of 1 gal. of fluid	8.65
Temperature of fluid	120.20
Percentage of salt water in fluid	88.30
Percentage of sand in fluid	1.50
Percentage of crude oil in fluid	10.20
Barrels of oil per hour	4.83
Specific gravity	0.90
Total depth of well in feet	1920.00
Size of casing, inches	6.00
Size of discharge line, inches	4.00
Height above ground to which fluid was pumped, feet	18.00
Total length of vertical discharge line	1516.30
Total length of vertical air line in well	1494.20
Well No. 32:	
Weight of 1 gal. of fluid, pounds	8.70
Temperature of fluid	114.50
Percentage of salt water in fluid	86.90
Percentage of sand in fluid	1.80
Percentage of crude oil in fluid	11.30
Barrels of oil per hour	4.90
Specific gravity	0.90

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Total depth of well, feet	1901.00
Size of casing, inches	6.00
Size of discharge, inches	4.00
Height above ground to which fluid was pumped	18.50
Total length of vertical discharge line	1513.00
Total length of vertical air line in well	1493.00
Size of air lines in well, inches	1.25
Barometer reading, inches of mercury	29.95
Dimensions of compressors, in.	10x22x16x20
Number operated	1
Kind of fuel used	Crude oil
Barrels of fuel used per hour	1.45
Price of 1 bbl. of oil at time of test, dollars	0.90
Cost in fuel of producing 1 bbl. of oil, dollars	0.074

This test was run in the same manner as those preceding, except that the fluid field was ascertained by means of a 2-ft. rectangular weir placed between the earthen fluid and oil pits, the salt water bleeds of the former having been closed. The old system used was that illustrated in Fig. 2. The depth of fluid over the crest of the weir was measured by means of the ordinary hook gauge calibrated to read accurately in hundredths of a centimetre. The weir constant was previously determined by testing in the usual way, using a sample of the fluid as pumped from the well.

A careful examination of the tests brings out several points that may require explanation. The loss of air pressure by friction in the small 1¼-in. air line in the well, to

TABLE 3. SUMMARY OF RESULTS

(Well No. 2, Mamou Power Company.)

	Old System.	New System.
Duration of tests, hours	10.000	10.000
Mean i.h.p	99.100	62.800
Mean w.h.p.	9.850	1.360
Mean a.h.p.	82.500	50.400
Gallons of fluid per second	0.694	0.849
Gallons of fluid per hour	2499.600	3056.400
Barrels of fluid per hour	54.750	72.770
Weight of 1 gal. of fluid, pounds	8.720	8.750
Mean temperature of fluid, deg. Fahr	118.300	117.900
Percentage of salt water in fluid	87.700	86.100
Percentage of sand in fluid	1.200	1.600
Percentage of crude oil in fluid	11.100	12.300
Barrels of oil per hour	6.080	8.950
Specific gravity of oil	0.900	0.900
Barometer reading, inches of mercury	29.940	29.930
Weir constant	24.390	24.390
Pumping constant	97.100	202.900
Total depth of well in feet	1901.000	1901.000
Size of casing, inches	6.000	6.000
Height above ground to which fluid was pumped, feet	3.330	3.330
Size of discharge line used, inches	4.000	4.000
Size of air line in well, inches	1.250	1.250
Total length of vertical discharge line	1500.000	1500.000
Total length of air line in well	1489.500	1489.500
Dimensions of compressor, inches	7½x18x16x16	7½x18x16x16
Number operated	1	1
Kind of fuel used	Crude oil	Crude oil
Gallons of fuel used per hour	44.2200	30.5300
Barrels of fuel used per hour	1.0500	0.7270
Price of 1 bbl. of oil at time of test, dollars	0.8500	0.8500
Cost in fuel of producing 1 bbl. of fluid, dollars	0.0163	0.0085
Cost in fuel of producing 1 bbl. of crude oil, dollars	0.1280	0.0690

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which the footpiece of the new system was attached, was approximately determined as follows: Pipe connections were made at the well top, so that by the manipulation of various valves the air from the main line could be sent either through the 1¼-in. air line or into the space between the well casing and the discharge line. By noting the pressure gauge readings in each instance, the friction loss (assuming that there is no loss by friction when air is forced between casing and discharge) is represented by the difference in the readings. Corrections were made, of course, for that part of the discharge line below the footpiece. It was impossible to obtain the actual friction loss in said 1¼-in. line by other means more accurate than those employed. While some error may be involved in assuming no friction loss in one instance, a comparison of the loss thus obtained with the theoretical loss is quite favorable, the former loss being the greater. Reference to table No. 3 will show that the working submergence of the new system is less than that of the old, in spite of the fact that there is the same amount of pipe in the well in each case. This is due to the additional drop in pumping head caused by the increase of fluid yield.

All calculations of submergence and pumping head were made from the observed air pressures after correcting for friction losses, etc. The mean of these calculations was verified as far as possible by actual measurement. This was done by shutting down the compressor after the well had been in steady operation for several hours and pulling the discharge line. The point at which the fluid stood, while the well was being pumped, was plainly defined on the pipe. The time required after shutting down the compressor to pull the first 'triple' from the well was a fraction less than two minutes. Comparison of the actual pumping head and submergence thus obtained with those obtained by calculations from the pressure gauge readings was in each case very close, a difference of 10 ft. 2 in. being the maximum.

Liquid Gas*

By WALTER O. SNELLING†

IT has long been known that during cold weather a liquid collects in exposed pipes at many natural-gas wells. At first the matter was regarded solely as a nuisance, since drip-tanks had to be installed to separate the liquid from the gas, and when a considerable quantity of the liquid accumulated in the tanks they had to be emptied.

That the liquid which thus collected in the drip-tanks was gasoline was probably recognized by many persons, but for a period of several years there appears to have been no realization of the significance of the fact, and practically no attempt was made to utilize the product. After some years of this waste, the collection and utilization of the gasoline seems to have come to the mind, at about the same time, of several men in widely separated localities. In the Pittsburg district the Robinson brothers appear to have been the pioneers in this development, and they made arrangements with the lessees of a number of gas wells, by which they were allowed to draw off the liquid from the drip-tanks, and dispose of it for a part of the profit realized.

The gasoline which was thus obtained was a perfectly transparent and colorless material, of very satisfactory grade. With systematic effort to collect this material came the observation that different sources of natural gas differed greatly in regard to the amount of gasoline which was produced, and the conditions under which it would separate.

Natural gas which came from the earth under high pressure would seldom give a liquid condensate, even in the coldest weather, while the very heavy gases which come from oil wells, and which are under very slight rock pressure, would frequently give an abundant supply of gasoline.

With the coming of summer, as the temperature outdoors became higher, even the amount of liquid which collected in the best wells became greatly lessened. It was to regain the profit which was thus found to be slipping away that the earliest efforts were

*Abstract from *Natural Gas Journal*, May 1912.
†Read before the Pittsburg Section of the American Chemical Society, April 5, 1912.

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made at compressing and cooling natural gas, in the efforts to separate from it the gasoline which it holds in the form of vapor.

It was found possible to prepare gasoline of excellent quality by simply compressing the natural gas in an ordinary air-compressor, and then passing the compressed gas through cooling coils, connected to a suitable drip-tank from which separated gas could be drawn off. From the heavy or 'wet' natural gas of oil wells it is not uncommon to get six or seven gallons of gasoline from each thousand cubic feet of gas treated, and there are many gasfields from which three to four gallons of gasoline per thousand cubic feet of gas may be obtained.

Even with compression and cooling, it is not possible to produce gasoline from natural gas which comes from the earth under high rock pressure, and this is naturally to be expected, since such gas consists almost entirely of methane, and the natural pressure which exists in the earth has been sufficient to prevent its carrying any considerable amount of the heavier hydrocarbons.

At the present time the industry of producing gasoline from natural gas has assumed large proportions; some hundreds of plants are already in operation, and the aggregate production has reached many thousand gallons per day, most of which is sold as a blended product, composed of a mixture of refinery naphtha and natural-gas gasoline; this blended product giving excellent results for all the purposes for which ordinary refinery gasoline is used.

With the earliest attempts at utilizing the new gasoline, attention seems to have been called to the fact that it was in nature not identical with ordinary or refinery gasoline. Some natural-gas gasoline contains dissolved gases to such an extent that when resting quietly in a glass vessel it effervesces or 'boils' strongly, and gives off vapors so rapidly that its volume is greatly reduced by standing, even for a period of an hour or so. That the vapors thus given off formed an explosive mixture with air was forcibly shown by a series of accidents which were associated with the early efforts in the use of natural-gas gasoline. It was in the effort to find a means of separating natural-gas gasoline from its dissolved gases, that my first studies in connection with this subject were made.

Repeated efforts had been made to separate the dissolved gases by distillation. In many cases the gasoline produced at the compressor had been placed in steel vessels heated by steam coils, and there warmed until a half or more of the gasoline had been evaporated. Even after this wasteful treatment the remaining gasoline was found to contain dissolved vapors to such an extent that it gave abnormal pressures when tested, and gave off gases to such an extent as to be considered dangerous.

Efforts were made by some of the producers of natural-gas gasoline to free their product from dissolved gases, by exposing the material to the air, in shallow tanks, and I understood that at one plant over 75% of the condensate produced was allowed to evaporate into the air, in the effort to obtain a satisfactory product; but even in this extreme case the tendency of the vapors which escape to carry with them the heavier products, and the tendency of the heavier residue to still retain a portion of the dissolved gases, made this method not wholly successful, even after three gallons of condensate out of every four gallons produced had been allowed to go to waste in the air.

After considering the matter for some time it came to me as a happy inspiration to try to utilize the critical pressures of the different gases as a means for their separation. It is well known to physicists that there is for each gas a critical temperature, above which no amount of pressure, however great, will reduce it to the liquid condition.

It seemed to me that by some suitable arrangement it ought to be possible to volatilize a mixture consisting of ethane, propane, butane, pentane, and hexane, for example, and then under high pressure to introduce into such mixture a coil heated by means of superheated steam or hot water to such a temperature as to be above the critical temperature of ethane and propane, for example, but below the critical temperature of butane, hexane, and pentane; and under these circumstances it seemed natural to suppose that the liquid which was separated by means of the coil would consist mainly of butane, pentane, and hexane, and that the ethane and propane would be left as uncondensed gases, to be condensed as a subsequent operation. I carried out some experiments with this method, and found it to be all that I had hoped.

By means of a series of coils, heated to

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different temperatures intermediate between the critical temperatures of the different gases, I found it possible to fractionate the vapors from natural-gas gasoline, so as to obtain as one fraction gasoline equal in every respect to the best refinery gasoline, and this result was achieved without the loss of any of the original products.

The critical temperature of a gas is a physical constant, and is not changed by pressure; and the selective condensation of vapors under very high pressure (up to 1000 lb. per square inch) upon hot coils higher in temperature than the critical temperature of part of the gases present, promises to give important and valuable results, not only in the preparation of liquid gas, but also in other refining operations. In its nature the new process of refining is entirely different from the ordinary method of fractionation by distillation.

The material which condenses upon the last coil in the series consists of ethane and propane, two gases which may be readily changed to the liquid condition by pressure and cooling, but whose boiling points under normal conditions of pressure are many degrees below 0°C. That these gases, liquefied and contained in strong steel cylinders, would form an ideal illuminant, seemed evident, and I at once carried on further experiments to determine the possibility of so producing and utilizing them.

At about this time my attention was called to the work which was being done by Frank P. Peterson of Grove City, Pennsylvania, and of C. L. Kerr of Pittsburg, Pennsylvania. Both of these gentlemen were making efforts to harness the enormous supply of energy which was slipping away in the form of wasted natural gas.

Mr. Peterson had made successful efforts to condense the lighter gases remaining after the separation of gasoline from natural gas, and to obtain a liquid product which he believed might be suitable for use as a substitute for Pintsch gas in the lighting of cars; and Mr. Kerr and his cousin, A. N. Kerr, had also carried out experiments along a somewhat similar line.

We all realized that the problem, which we had each approached from a different angle, was capable of solution by the joint methods which had been worked out; and, making use of the liquid product produced through the stage-compression method of Mr. Peterson, I found it possible to effect, by the method which I already explained, a complete rectification of the material, thus obtaining a liquid gas which could at all times be produced of uniform quality and without the waste of any portion of the original gas.

The results which had been obtained are now so well known that it is not necessary for me to refer to them in detail. Tests made with great care have shown that it is possible to produce from natural gas, by a combination of the methods of stage compression and rectification, not only gasoline of the most excellent quality, and equal in every respect to the best grades of refinery product, but, in addition, to recover all of the ethane, propane, and butane, as a liquid gas, in such a form as to make it a convenient, safe, clean, and cheap method of lighting isolated dwellings, such as country homes, seaside resorts, lighthouses, and lightbuoys.

For many years the waste of natural gas in the United States has reached enormous proportions. I. C. White, State Geologist of West Virginia, has in particular called attention many times to the enormous extent to which natural gas and oil-well gas was being allowed to escape, with the consequent loss to the nation of the equivalent in heating power of many millions of tons of coal.

This waste no longer seems necessary, since it is those very gases from oil wells, which have up to now been the most difficult to utilize in pipe-lines, etc., that are best adapted to the production of liquid gas and gasoline by the new methods.

Plans are already under way to utilize some millions of cubic feet of gas daily in the production of gasoline and liquid gas, and thus to add decidedly to the national supply both gasoline, a material which is finding each day ever-widening uses, and liquid gas, a product which seems destined to play a large part in the lighting of isolated dwellings.

The name 'Gasol' has been given to the liquid gas produced by the new process. When under a pressure of 500 lb. to the square inch it exists as a clear, transparent liquid. When the pressure is lessened it changes into gas, and at normal or atmospheric pressure this gas is, unlike the gas produced by blowing air through gasoline, for example, extremely dry, and does not give any liquid condensate in the pipes, all

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of the hydrocarbons which so condense having been separated in the process of rectification, and going into the gasoline product.

One volume of liquid 'Gasol' produces about 350 volumes of gas upon release of pressure, and the gas so produced has a heating value of about 22,000 calories per litre, or about 2400 b.t.u. per cubic foot.

When it is remembered that the heating value of ordinary coal-gas is only about 600 b.t.u. per cubic foot, and manufactured oil-gas is less than 650 b.t.u. per cubic foot, it will be seen that the new gas has about four times the heat-producing capacity, when equal volumes are considered, of either coal-gas or manufactured oil-gas. In addition its flame temperature is much higher, being decidedly higher than the flame temperature of natural gas or any other of the common gases used for heating.

The flame temperature of ordinary natural-gas burning in air is about 2150°, and the flame temperature of ethane burning in air is about 2205°. The flame temperature of the new gas is about 2300°, and since the amount of light produced from the Welsbach mantle bears an important relation to the temperature of the flame, the reason is here seen for the remarkable brillancy of the light produced by the new gas.

It must be remembered that the preparation of liquid products from natural gas is itself not new, and liquid gas has been prepared from oil by destructive distillation, and also from coal and from natural gas.

In connection with the preparation of a high-pressure liquid gas from natural gas, Frank P. Peterson has made important inventions, and C. L. Kerr, A. N. Kerr, T. G. Phinney, and others have done important pioneer work. The new process of preparing a liquid gas of perfectly homogeneous nature and uniform composition is the culmination of the work of many men, and of several years of experimenting. It opens to the use of the world the enormous volumes of oil-well gas now so generally wasted, and produces from this waste material a product which gives to the country home all of the conveniences of gas for lighting and cooking, thus giving to the farm, advantages which have been up to now available in general only to the city.

No manual adjustment is necessary with the new gas. It is perfectly uniform in composition and in action, and in all experiments so far made it seems to afford an ideal medium for the lighting of lighthouses, light-buoys, and all similar purposes, and for the lighting of isolated dwellings of all kinds.

The Diesel Engine From the User's Standpoint*

By WILLIAM J. U. SOWTER

THE Diesel engine is coming into such general use for the purpose of the generation of electrical energy that a few notes on its advantages, cost of running and maintenance may be of interest.

The quantity of cooling water required is considerably less than that required by suction-gas or steam plants. With an inlet temperature of 50°F. and an outlet temperature of 140°F., about 3 gal. per brake horse-power is required. Taking the case of a 250-b.hp. engine, and assuming the loss due to evaporation and leakage to be 10%, the cost of water at 6d. per 1000 gal. will amount to 0.45d. per hour. The Diesel engine is capable of working satisfactorily and economically on a wide range of fuels without any alteration or adjustment. The standard fuel is crude Texas or Rumanian oil, which may be purchased at prices ranging between 35s. and 70s. per ton. The oil can be purchased in London at about 40s. per ton. The following is a specification of a suitable oil which I have adopted with satisfactory results: (1) the oil shall be crude, refined, or a residue of petroleum; (2) it shall be free from tar, bitumen, or solid hydrocarbons, sand, fibrous matter, or foreign solid impurities; (3) the oil shall not contain more than 0.5% of water nor 1.5% of sulphur, and shall be free from acid; (4) the viscosity shall be such that the oil will flow in a continuous stream with 1-ft. head through a ½-in. copper pipe 6 ft. long without being heated; (5) the calorific value shall not be less than 18,000 b.t.u. per pound.

*Abstract from *Mechanical World*, July 26, 1912.

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Many other liquid fuels may be used, such as residue shale oil, gas works tar oil, or creosote oil.

Contrasted with steam plant, there is but little difference in fuel consumption per brake horse-power between large and small Diesel engines, nor does the fuel consumption increase largely per unit of energy as the load is decreased on the engine. It is apparent from the foregoing remarks that it is unnecessary from the point of view of fuel economy to install large engines when a greater number of small engines will suit the circumstances of any particular case better, desirable as the former procedure may be, so far as capital cost per kilowatt of plant installed is concerned. The following figures show the cost of fuel per unit generated with oil at the prices mentioned, and at various loads, for a 50-b.hp. engine coupled to a 33-kw. generator:

Load.	Dynamo Efficiency, %.	Price of Fuel per Ton. 40s.	50s.	60s.	70s.
Full	88	0.161	0.201	0.242	0.281
Three-quarter.	86	0.178	0.210	0.252	0.295
Half	83	0.208	0.261	0.314	0.365
Quarter	78	0.307	0.384	0.462	0.538

A steam plant, if not properly maintained, becomes more and more uneconomical as time goes on, but still the plant continues to run as though all were in order, with an increased fuel consumption; on the other hand, internal-combustion engines—and particularly the Diesel engine—must be maintained in thorough good order, otherwise there will be great difficulty in getting them to run at all; therefore, those in charge of such plants are bound to see that they are carefully attended to, and when in good order the fuel consumption must always be normal, while, as we have seen, the steam plant, if in bad order, can still be run, but at great expense as regards fuel.

The capital cost of a Diesel engine direct-coupled to a generator is considerably greater than a gas or steam-driven generator of similar capacity; but when the cost of complete plants, comprising either gas or steam, is compared, there is but little difference in the price per kilowatt. A Diesel station, however, requires less land and buildings than similar stations employing steam or gas plant, so that the difference, if any, is in favor of the Diesel plant. The following are approximate prices for small plants, delivered and erected on purchaser's foundations, complete with oil-storage tanks, piping, etc., and may be taken as fairly representative:

Size in Kw.	Price.	Price per Kw.
100	£1950	£19.5
150	2600	17.3
200	3260	16.3
300	4380	14.6
400	5300	13.3

The useful life of a generating plant is an important factor for consideration, and one which must of necessity be taken into account in considering the working costs of any undertaking. It has been said from time to time that the stresses set up in an engine of the Diesel type are extremely violent, and in order to support that view, attention has been drawn to the heavy and solid construction of the engine. As a matter of fact, however, the stresses are no more severe than those met with in ordinary gas-engine practice. The solidity of the parts is really due to the fact that the engine is single-acting, and gives only one impulse per two revolutions, as compared with two impulses per one revolution in the case of the single-cylinder, double-acting engine; hence the parts must necessarily be proportionately strong. The driving parts of, say, a 50-b.hp. Diesel engine require to be of the same strength as similar parts of a single-cylinder, double-acting steam-engine of 200-b.hp. I am of opinion that the life of the Diesel engine should be equally as long as that of a well-built steam-engine. The only expensive part likely to require replacement is the cylinder liner. It is essential that the compression should be maintained, and all I can say on this point at present is that I have had an engine running for over two years, and that no appreciable wear of either the liner or piston rings has yet occurred. It appears, therefore, that the life of the liner may be computed at ten years at least. The valves are fitted into removable casings, which can be renewed at a small cost. As most of the other parts, such as springs, pump plungers, air pipes, and so on, are quite light,

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cheap, and easy to replace, it appears that the cost of maintenance of this type of engine must be very much less than a complete steam plant, considering that the engine takes the place of a steam-engine, boiler, steam-pipes, feed-pumps, economizer, chimney, and the numerous small items incidental to a steam installation, all of which require frequent attention.

Although the Diesel engine possesses many advantages, it is undoubtedly true that in order to secure reliability, first-class attention is necessary. The various points which need regular attention can only be ascertained from practical experience, but when that experience has been gained and intelligently applied, there is no reason why the running and reliability of the plant should not be at least equal to steam, and vastly superior to a gas plant. Smooth running very largely depends upon the man in charge of the plant, and it may safely be said that 90% of the trouble experienced in the running is due to the neglect of the attendants. It may be assumed that Diesel engines require considerable supervision, and that it is advisable to employ men of skill and experience rather than mere laborers. Even taking this into consideration, the cost of labor on moderate-sized plants is substantially less than that necessary with a steam plant.

It is of importance that a suitable grade of oil should be chosen; the oil must be a pure mineral one with a high flash point. Suitable oil, however, is not necessarily expensive. I am using ordinary crank-chamber oil, costing 1s. 5d. per gallon, with perfectly satisfactory results. Although it is claimed that the cost of lubrication of a Diesel plant is no greater than that of a good steam-engine, such is not my experience, the cost in my case being about 50% greater. While efficient lubrication is essential, the use of an excessive quantity of oil should be avoided. The piston and gudgeon pin are lubricated by a pump which forces the oil through a hole in the liner and piston to the pin, and also through an angular space between the liner and cylinder casting. There are generally about six holes, about 1/32 inch in diameter, drilled through the cylinder at this point, and through which the oil is forced to meet the piston. Should the oil be dirty, or contain carbon, these small holes readily become blocked, cutting off the supply of oil to the piston. Oil, after collection from the crank pit, contains a certain amount of carbon, and should be placed in a settling-tank, preferably heated by a steam coil, or if a supply of steam is not available, an electric heating arrangement of some kind. After a sufficient time has elapsed for settling, the oil should be drawn off from the top and passed through a good filter before use. I have found that it is practically impossible to remove the whole of the carbon from the oil, and consequently, if the oil is used repeatedly, more and more carbon will be fed into the cylinders and other parts until there is a sufficient accumulation of carbon to cause a stoppage of the lubricating passages. As a seizure of the piston might cause serious damage to the engine, and as it is naturally necessary to economize in lubricating oil as much as possible, I recommend that the piston should be drawn every six months and the lubricating passages cleaned. The carbonization of oil may also cause trouble in the air-compressor cylinders. Before I realized this possibility, filtered oil was always used in the compressor, and probably to excess. In the course of time the high-pressure air-pipe leading from the compressor to the intercooler blew off at the joint, when it was discovered that the pipe was completely blocked with solid carbon.

Owing to the high compression which must be maintained, it is necessary to keep the valves quite tight, otherwise leakages will occur, reducing the compression, which renders it very difficult to start the engine, and when started proper combustion of the fuel is not secured. I suggest a system whereby each valve is examined and ground at stated intervals. I have found that, under the conditions in which I am working, the valves will run without any attention for the following periods: exhaust, 600 hr.; air, 2000 hr.; fuel, 600 hr.; and starting, one year. In order to insure that the valves are maintained in good order, the running hours of the plant should be logged and a record kept of the date each valve was examined and ground; it is then an easy matter to see when each valve is due for attention. Spare valves and casings are supplied with each engine, which can be changed in a few moments, and the valve and casing

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removed can be ground at the attendant's leisure. The needle or fuel valve is so adjusted that the fuel spray is blown into the cylinder two or three degrees before the crank reaches the top centre on the compression stroke. It is very important that this valve should be properly set and quite tight; if there is any leakage, fuel will be admitted at the wrong time, resulting in irregular running of the engine. This pulverizer is liable to become choked if the fuel is dirty and insufficiently filtered; it should therefore be examined and cleaned at the same time as the needle valve. A clogged pulverizer may cause difficulty in starting, or reduced output, owing to insufficient fuel passing to the cylinder.

A considerable quantity of vapor is carried into the compressor, the quantity depending upon the humidity of the atmosphere. When the air from the compressor is cooled in the inter-cooler the vapor is condensed, and unless the drain on the inter-cooler is blown down frequently, water is carried over into the air-storage receivers. The water naturally causes rusting of the interior surfaces, and also, as the air in the bottles will absorb moisture, rusting of the steel pipe leading to the starting valve may occur. The rust is carried along from the receivers and pipe to the starting valve, where it will accumulate, eventually causing the starting valve to stick. If this occurs, the contents of the bottle may be lost before the valve can be shut. The only precaution necessary to avoid this annoying experience is to see that the inter-cooler drain is blown down at regular intervals, say every half-hour, particularly in damp weather. The air-storage receivers are provided with siphons and drains, and should be drained every day. The compressor high-pressure suction and delivery valves require grinding in about every 600 running hours, and the low-pressure valves about every 2000 hr. If the inter-cooler drain is not blown down frequently enough, or if too much lubricating oil is used, the valves may hang up. This can usually be remedied by repeatedly blowing down the inter-cooler drain until the accumulation of oil and water is removed. It is well to draw the compressor pistons every six months, and clean off the accumulation of carbonized oil which is deposited on the top. It is also advisable to clean the air inlet and passages to the low-pressure valves at the same time.

Defective starting is generally due to one of the following causes: (1) low compression; (2) defect in oil pump or oil supply; or (3) incorrect adjustment of fuel, air, or exhaust valves. Low compression is most commonly due to a bad condition of the valves and is an indication that they require grinding. It may happen that if the engine is overheated, due to defective water circulation or overloading, the valve casings may be distorted, resulting in a leakage between their joint faces and seatings in the cylinder head. If no leakage is apparent from examination, the application of the indicator will speedily determine whether the compression is low. The fuel oil pump is usually arranged so that it can be disconnected from the engine and fitted with a temporary means of operating it by hand for the purpose of filling the delivery pipes with oil after they have been disconnected for any reason. Also the delivery pipe from the fuel pump is fitted with a by-pass worked from the starting lever controlling the fuel and starting-cam levers. The by-pass is so arranged that when the engine is started on compressed air no oil is delivered into the fuel valve casing until the starting lever is put into the running positon. If no such by-pass were fitted, the needle-valve casing would be filled with fuel pumped in while the engine was running on compressed air, and when the starting lever was thrown into the running position, and the fuel valve opened at its proper time, too large a charge of oil would be admitted to the cylinder, which might cause damage. If it is suspected that fuel oil is not reaching the cylinders, the fuel pump should be overhauled, and its valves, as well as the by-pass valves, examined and ground if necessary. If the by-pass valves are not perfectly tight, oil may leak away instead of passing into the fuel valve, when starting would naturally be difficult, or even impossible. The setting of the needle valve may readily be tested by turning over the engine until the crank is near the firing centre; compressed air should then be admitted to the blast pipe, the indicator cock opened, and the engine slowly turned over until air begins to issue from the indicator cock. This is the point at which the fuel valve begins to open, and should correspond

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with the maker's setting marks. The air and exhaust valves should begin to open at the proper time, and in order to insure this, most makers stamp on the engine the clearance there should be between the cams and the rollers at a marked point. These clearances should be checked periodically, and adjusted if necessary. If the engine is kept in good order, and the above points carefully attended to, there should be no difficulty experienced in starting easily and certainly.

The exhaust should be smokeless; black smoke may be emitted if the blast pressure is too low, or if the engine is overloaded. If all is in order the exhaust should be colorless, indicating perfect combustion of the fuel. The exhaust gases escape from the engine at a pressure of about 40 lb. per square inch, and it is necessary that adequate measures should be taken to allow the escaping gases to expand gradually, or nuisance may be caused to the surrounding neighborhood. For most situations the cast-iron silencers provided with the engines will be quite effectual, but I had some trouble due to the fact that private residences are in close proximity to the works. The exhaust, therefore, was led to a large concrete pit, which removed all cause for complaint. It is my intention to lead the exhaust from a 150-b.hp. engine, shortly to be installed, to the base of an existing chimney stack 120 ft. high, which should deal with the difficulty in an effectual manner. In steam-driven stations where extensions are carried out by adding Diesel engines, the use of exhaust boilers would be a further source of economy, enabling the waste heat from the exhaust of the Diesel engines to be utilized on the steam side. Exhaust boilers also are a useful means of providing hot water in factories where such is required for the process of manufacture, and Diesel engines are installed for the provision of the necessary power required.

Waterproof Concrete*

By ALBERT GRITTNER †

(Translated from the German by H. Borns.)

THE application of fluates for the preparation of waterproof concrete has long been known. The operation requires much time and labor; for the desired object can only be realized by applying the fluates several times. Endeavors have hence been made to find other materials which would render concrete waterproof, when mixed with it, and which would be obtainable at lower cost and be applicable with less trouble.

I have been investigating two such materials, namely, 'biber' and 'aquabar.' The experiments which I have been conducting have not led to any satisfactory results, although I applied the materials as prescribed by the manufacturers. These tests have further proved that biber may be replaced by common coal tar oils, and that equally good but unsatisfactory results are obtained without the latter. The substitution for aquabar, which is a soap solution, of a solution of an ordinary washing soap, has not been successful. But when common soap, which is a soda soap, was replaced by a potash soap, I realized not only favorable but indeed surprising results.

Before I pass to these experiments with potash soap, I should like to refer to the results which I obtained in my fluate experiments. For these experiments I used a portland cement and a fine-grained artificial sand obtained from a Karst limestone. The sand consisted of 58% of grains less than 3 mm. in size, and 42% of grains more than 3 mm. in size. For testing the fluates, hollow cubes were prepared of 7-cm. edge and 1-cm. wall-thickness. In order to determine the height of capillary suction, prisms were also made, 21 cm. in height and 5 by 5 cm. in cross-section. Finally discs were prepared, 9 cm. in diameter and 1 or 3 cm. in thickness, and were subjected to water-pres-

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†Budapest.

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sure tests in a Böhme apparatus. Portland cement tested in accordance with the standard Hungarian specifications showed after 28 days a tensile strength of 37.4 kg. and crushing strength of 444 kg. The applied solution of magnesia fluate was 20°B. The specimens were made so that the density of the finished specimen was 2.31. The following were the results obtained:

mixture ratio	water, per cent of weight of cement	cement in kg per m³ of mortar	waterproof in which condition	consumption of fluate in kg per m²	suction rise in cm in the prisms after 24 hours	water, in grs. penetrating under pressure of 2·1 atm. per cm² through disc thickness of		water taken up by hollow cubes after 24 hours, in per cent of weight of the cubes	
						1 cm	3 cm	per cent	Note
1:3	50	458	without fluate	—	6	0·78	0·41	19·6	water height inside 3 cm
			fluate 2 times	0·4	5	0·31	0·24	9·2	water height inside 1 cm
			fluate 4 times	0·7	3	0·12	0·04	1·2	inner surface all moist
			fluate 6 times	0·9	1·5	0·04	0·00	0·7	moist in one spot

The prisms and hollow cubes stood in 4 cm. of water; the latter were covered with glass plates to prevent any evaporation of the infiltrated water. The tests show that waterproofing can only be realized after applying several coatings of fluate, which would render the process too expensive. My potash-soap experiments were started at the instigation of C. Zielinszky, professor at the technical high school of Budapest, who had obtained good results when using potash soap on a concrete building. The portland cement used in these experiments showed after 28 days a tensile strength of 31.8 kg. and crushing strength of 440 kg. The river sand used was fine grained, 94% being less than 3 mm. in size. The density of the sand was 1.52. The gauge-liquid consisted of a soap solution containing 8 kg. of potash soap in 100 litres of water. It should be emphasized that the soap must be completely dissolved, which is best secured by taking care to use warm water and to filter subsequently through some loose fabric. The density of the specimens was 2.22. After being kept damp for 28 days, the specimen was placed on a hot stove and completely dried. When the tests were finished, the specimens were once more dried at 120°C. and again tested in order to ascertain whether the capacity for keeping the water out had not altered. The results were the same in the first and in the second instances. The dimensions of the specimens were the same as those used for the fluate tests. The table on next page shows the results.

It was striking and indeed surprising to find in the case of these soft-soap test specimens, not only that the hollow cubes and the prisms were completely waterproof, but also that the disc, 1 cm. in thickness, could maintain a water column of 85 cm. without sinking after 8 days. Still more striking is the experiment in which the disc of 3-cm. thickness withstood a pressure of 2.1 atmospheres for 24 hours without showing any permeation of moisture.

This experiment demonstrates conclusively that a dense concrete which has been prepared with soft soap will be completely impervious to water without necessitating the laborious operations required for a successful application of fluates.

It is not only this experiment which proves the accuracy of the facts that have been ascertained. Practical experience confirms this experiment. The tank of the water tower on Margaret isle in Budapest, 600 cubic metres in capacity, was prepared with potash soap, after experiments with hollow cubes had proved the concrete which was used to be completely impervious to water. The preparation of such concrete

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mixture ratio	liquid in per cent of cement	cement in kg per m³ of mortar	crushing strength after 28 days	suction rise in prism in cm		water column of 85 cm sinks in the disc, 1 cm in thickness, to cm		a water pressure of 2·1 atm. forces through disc of 3 cm in 24 hrs. per cm² grammes of water	water taken up by hollow cubes in percent of weight of the cube		Note
				1 hour	24 hrs.	24 hrs.	8 days		24 hrs.	8 days	
1:2·5	40	563	242	2	5	83	81	88	2·5	4·0	wet through, water has entered
			212	0	0	85	85	0	0	0	perfectly dry

with potash soap is not expensive. A cubic metre of concrete would at the most cost only 10 kronen (8s. 6d.) additional. It is true that a firm and quite dense concrete, free of voids, which has been carefully prepared and faced with cement, will also be waterproof; but this object can be attained by the aid of potash soap with much less trouble and care at much smaller expense.

One important question remained to be investigated. It must be admitted that a considerable saving might be effected, if the same object could be attained by using smaller quantities of cement. The question was: is it really absolutely necessary that the cubic metre of concrete should contain 500 kg. of cement? Might not the desired end be secured with 300 kg. of cement? I therefore conducted some experiments in which a cubic metre of finished concrete contained only 300 kg. of cement. For these tests I prepared hollow cubes with 20 cm. of edge, the wall thickness being 4 cm. The specimens were made with portland cement, which after 28 days yielded: tensile strength, 34.2 kg.; crushing strength, 337 kilograms.

The Danube sand used for these experiments had a density of 1.62, and the volume of the pores amounted to 35%. The coarse additions consisted of Danube pebbles of 2-cm. diameter at the highest, a density of 1.59 and a pore volume of 39%. The concrete was made with 71.5% of water and 8% of soap solution (calculated for the cement applied) and was kept damp for three weeks before being submitted to the test. We also made from this concrete prisms of 21 cm. edge length and 5 by 5 cm. cross-section. These were likewise kept in the damp for three weeks and afterward dried in the stove at 100°C., and then placed in 10 cm. of water in order to determine the amount of water taken up by the specimen.

The results are tabulated below. I should add that I also prepared cubes of 20-cm. edge for the pressure test, and that the resulting strengths tabulated are means of three experiments.

mixture ratio by weight	liquid added	amount of liquid in per cent of cement	cement in kg per m³ of mortar	crushing strenght after 28 days	Sinking of the level of the 2·1 of water in cube 150 mm water depth after				weight of prism after standing in 10 cm of water; grammes			water pressure of 2·1 atm. forces through disc of 3 cm thickness after 6 days per dm² grammes of water	Note
					1 day	2 days	1 week	2 weeks	originally	1 day	1 week		
1:1·5:2·5	water	71·5	300	83·2	10	15	42	65	1162	1223	1245	38·4	The discs werth dried after 3 weeks
	soap.		294	75·0	1	1·5	2	3	1176	1184	1194	0	

These experiments demonstrate that a waterproof concrete can also be obtained by the aid of a potash soap if 1 c.c. of concrete does not contain more than 300 kg. of portland cement. Just like the previous

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tests with 500 kg. of cement, these tests demonstrated that the discs 3 cm. in thickness, when exposed to a water pressure of 2.1 atmospheres for 6 hours, did not permit the smallest quantity of water to permeate; they did not even turn damp when potash soap had been used in their preparation. The same discs were completely wetted through in one hour when they had been prepared with water. When a waterproof concrete is to be made with potash soap, the chief condition to be observed is that the concrete should be perfectly dense; that is to say, free of voids. The pores between the sand particles should be entirely filled with cement; but since this would require a great deal of cement, it is important to know that the mortar may be mixed with pebbles and crushed stones, such that part of the volume of the pores is filled by this material, which is imbedded in the mortar. As a result of these experiments I have reached the following conclusions:

CONCLUSIONS

1. A waterproof concrete can be prepared by the application of fluates. The operation, however, requires a great deal of time and labor.

2. By the application of an 8% solution of potash soap, instead of water in mixing, the concrete can be rendered waterproof, so as to fulfill all requirements as to impermeability to water.

3. In order to prepare waterproof concrete with the aid of potash soap, we have to apply at least 300 kg. of a good portland cement per cubic metre of concrete. When the cement is of a less superior quality, it will be advisable to take 500 kg. of cement per cubic metre of concrete.

I conclude that a waterproof concrete which will satisfy all requirements can be obtained with the aid of a potash soap solution of 8% when from 300 to 500 kg. of portland cement is used per cubic metre of concrete.

Definitions and Equivalents for Irrigation and Hydraulic Computations

By WILLIAM H. KRITZER

TERMS IN WATER MEASUREMENT

The volume of water flowing in a stream—the 'run-off' or 'discharge'—is expressed in various terms, each of which has become associated with a certain class of work. These terms may be divided into two groups: (1) those which represent a rate of flow, as second-feet, gallons per minute, miner's inches, and run-off in second-feet per square mile; and (2) those which represent the actual quantity of water, as run-off in depth in inches and acre-feet. They may be defined as follows:

'Miner's inch' is an ambiguous term and at present is used in an indefinite sense, no less than three being in use. It is the rate of discharge of water that passes through an orifice 1 inch square under a head which varies locally. It may be taken for all practical purposes as equivalent to 1.5 cubic feet of water per minute, or in other words, one cubic foot per second equals 40 miner's inches. Its value is defined by statute in each state in which it is used, and in California it is 1/40 of a cubic foot per second, or 11.23 gallons per minute. In southern California, except in legal matters, the old miner's inch, the value of which is 1/50 of a cubic foot per second or 9 gallons per minute, is still retained as the unit of measurement by all the irrigation and water companies.

'Second-foot' is an abbreviation for cubic foot per second and is the rate of discharge of water flowing in a stream 1 foot wide, 1 foot deep, at a rate of 1 foot per second.

'Second-feet per square mile' is the average number of cubic feet of water flowing per second from each square mile of area drained, on the assumption that the run-off is distributed uniformly both as regards time and area.

'Run-off in inches' is the depth to which the drainage area would be covered if all the water flowing from it in

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a given period were conserved and uniformly distributed on the surface. It is used for comparing run-off with rainfall, which is usually expressed in depth in inches.

'Gallons per minute' is generally used in connection with pumping and city water-supply.

'Duty of water,' or the amount of water called for in acre-feet per year, to produce agricultural growths, varies with different sections, the climate, the soils, crops, etc.

If water is to be stored for irrigation purposes, it is customary to provide from three to four acre-feet of storage capacity, depending upon the probable losses in delivery, for each acre of land to be watered.

EQUIVALENTS OF CUBIC MEASUREMENTS

Water is the most dense, or occupies the least space, when at a temperature of 39.2° Fahrenheit.

1 cubic inch of water weighs 0.036125 pound, or 0.577 ounce.

1 cubic foot of water weighs 62.4245 lb. (fresh at 62°F.).

1 cubic foot of water weighs 63.976 lb. (salt at 62°F.).

1 inch of rainfall per hour per acre equals 1 cubic foot of water per second (approximately).

1 cubic foot of water per second is equal to 40 miner's inches, or 450 gallons of water per minute.

5 gallons of water per minute, per acre, delivered 24 hours per day, will cover an acre of land 24 inches deep in 90 days. It is frequently termed two acre-feet in a season.

225 gallons of water per minute, or 25 miner's inches, is sufficient to cover 1 acre, 1 inch deep, in 2 hours and 1 minute.

EQUIVALENTS OF MINER'S INCHES

1 miner's inch equals 0.02499 cubic foot of water per second.

1 miner's inch equals 1.4994 cubic feet of water per minute.

1 miner's inch equals 89.9640 cubic feet of water per hour.

1 miner's inch equals 2159.1460 cubic feet of water per day.

1 miner's inch equals 0.1496 gallon of water per second.

1 miner's inch equals 8.976 gallons of water per minute.

1 miner's inch equals 538.56 gallons of water per hour.

1 miner's inch equals 12,925.44 gallons of water per day.

1 miner's inch under 4-inch pressure equals 1 acre-foot of water in 25 days.

1 miner's inch under 6-inch pressure equals 1 acre-foot of water in 20 days.

1 miner's inch will flood 10 acres of land 1.45 feet in depth in 1 year; or 14.49 acres 1 foot deep; or 18.11 acres 9 inches deep.

100 California miner's inches equals 18.7 U. S. gallons of water per second.

100 California miner's inches for 1 day equals 4.96 acre-feet of water.

100 California miner's inches equals 96.0 Colorado miner's inches.

5 California miner's inches will cover an acre of land with water 2.3 feet deep in 23 hours.

100 Colorado miner's inches equals 19.5 U. S. gallons of water per second.

100 Colorado miner's inches equals 5.17 acre-feet of water for one day.

100 Colorado miner's inches equals 2.60 second-feet of water for one day.

100 Colorado miner's inches equals 104 California miner's inches.

25 Colorado miner's inches equals 1 acre covered with water 1 inch deep, in 1 hour and 37 minutes.

1 Colorado miner's inch equals 11.2 U. S. gallons of water per minute.

1 Colorado miner's inch equals 1.5 cubic feet of water per minute.

1 Colorado miner's inch equals 0.25 second-foot of water per minute.

EQUIVALENTS OF SECOND-FEET

1,000,000 U. S. gallons per day equals 1.55 second-feet per minute.

1,000,000 U. S. gallons per day equals 3.07 acre-feet of water.

1,000,000 cubic feet of water equals 22.95 acre-feet of water.

100 U. S. gallons per minute equals 0.223 second-feet of water.

100 U. S. gallons per minute equals 0.442 acre-feet for one day.

1 second-foot of water equals 40 Arizona miner's inches.

1 second-foot of water equals 40 California miner's inches (law of March 23, 1901).

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1 second-foot of water equals 38.4 Colorado miner's inches.
1 second-foot of water equals 50 Idaho miner's inches.
1 second-foot of water equals 50 Montana miner's inches.
1 second-foot of water equals 50 Nevada miner's inches.
1 second-foot of water equals 50 New Mexico miner's inches.
1 second-foot of water equals 40 Oregon miner's inches.
1 second-foot of water equals 50 Utah miner's inches.
1 second-foot of water equals 50 Washington miner's inches.
1 second-foot equals 7.48052 U. S. gallons of water per second; equals 448.8 gallons per minute; equals 646,272 gallons per day.
1 second-foot equals 6.232 British imperial gallons per second.
1 second-foot equals about 1 acre-inch per hour, or 1 acre-foot in 12 hours.
1 second-foot flowing for 1 day equals 86.400 cubic feet, or 1 cubic foot per second run-off from 1 square mile would, if held upon this area, cover it to a depth represented by dividing 86.400 by the number of square feet in a mile, 27,875.400, or 5.280 squared. Completing the division, 1 second-foot for 1 day is equal to a quantity of water covering 1 square mile 0.003099-174 foot, or 0.037190082 inch.
1 second-foot flowing 1 day equals 1.983471 acre-feet.
1 second-foot flowing for 1 year equals 31,536.000 cubic feet.
1 second-foot for 1 year will cover 1 square mile 1.131 feet, or 13.572 inches deep.
1 second-foot on 80 acres, will during an irrigation period of 120 days, deliver water sufficient to cover the entire tract to a depth of 3 feet; that is, at the rate of ½ miner's inch to the acre.
1 second-foot equals 59.9 acre-feet of water in 30 days.
1 second-foot equals 724.5 acre-feet of water in 1 year.
1 second-foot equals 1 acre-foot in 12 hours 6 minutes.
1 foot-flow per second equals a velocity of 0.68 mile per hour.

EQUIVALENTS OF ACRE-INCHES

1 acre-foot equals 325,850 U. S. gallons of water.
1 acre-foot equals 43.560 cubic feet of water.
1 acre-foot equals the covering of 1 acre of ground with water 1 foot deep, or 2 acres of ground 6 inches deep, or 3 acres of ground 4 inches deep.
1 acre 1 inch deep equals 27.152 U. S. gallons of water.
1 acre 1 inch deep equals 3.630 cubic feet of water.
1 acre equals 43,560 square feet of land.
1 acre equals 209 feet square (nearly).
1 side of a mile square equals 5,280 feet.
1 square mile equals 2,323,200 cubic feet of water 1 inch deep.
1 square mile equals 0.0737 second-foot per year to cover land 1 inch deep with water.
1 cubic foot of water equals 450 second-feet of water per minute.
1 cubic foot equals 1 acre-foot of water in 12 hours.
1 cubic foot equals 40 miner's inches of water under 6-inch pressure.
1 inch of water under 4-inch pressure equals 12,960 of water in one day, equals 1/50 second-foot, or ⅛ of an acre-foot.
1 inch of water under 4-inch pressure equals 27,000 U. S. gallons per second-foot in 1 hour; 648,000 gallons per second-foot in one day.
1 inch of water under a 4-inch pressure equals 4,320 gallons per acre-foot in 1 hour, or 103,680 gallons per acre-foot in 1 day.
24,000 inches of water under a 4-inch pressure is equal to a continuous flow of 215,000 gallons per minute.

EQUIVALENTS OF WEIGHTS AND MEASURES OF WATER

1 pound of water equals 27¾ cubic inches.
1 ton of water equals 240.418 U. S. gallons.
1 ton of water equals 32.038 cubic feet (liquid space).
1 ton of water equals 35.5 cubic feet (frozen space).
1 gallon, U. S., equals 0.13368 cubic foot.
1 gallon, U. S., equals 231 cubic inches.
1 gallon, U. S., equals 8.33111 pounds.

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1 gallon, New York, equals 221.814 cubic inches.
1 gallon, New York, equals 8.00 pounds.
1 gallon, British imperial, equals 277.274 cubic inches.
1 gallon, British imperial, equals 10.005 pounds of water (fresh).
1 gallon, British imperial, equals 10.866 pounds of water (salt).
1 gallon, British imperial, equals 1.20032 U. S. gallons.
1 cubic foot equals 6.2321 British imperial gallons.
1 cubic foot equals 7.901 New York gallons.
1 cubic foot equals 2,200 cylindrical inches.
1 gallon, U. S., per minute equals 1,440 gallons, or 192.5 cubic feet, or 6 tons of water per day.
Acres × 0.4840 equal square yards.
Circular inches × 0.00546 equal square feet.
1 circular inch is a circle 1 inch in diameter.
1 circular inch equals 0.7854 of a square inch.
Cubic inches × 0.00058 equal cubic feet.
Cubic inches × 0.004329 equal U. S. gallons,
Cubic inches × 0.003607 equal British imperial gallons.
Cubic inches × 0.036024 equal pounds avoirdupois.
Cubic inches × 0.576384 equal ounces avoirdupois.
Cylindrical inches × 0.0004546 equal cubic feet.
Cylindrical inches × 0.002832 equal British imperial gallons.
Cylindrical inches × 0.0034 equal U. S. gallons.
Cylindrical inches × 0.02842 equal pounds avoirdupois.
Square inches × 0.00695 equal square feet.
1 square foot equals 183.346 circular inches.
1 square inch equals 1.27324 circular inches.
Square feet × 0.111 equal square yards.
Square yards × 0.0002066 equal acres.
Cubic feet × 0.03704 equal cubic yards.
Cubic feet × 7.48 equal U. S. gallons.
Cubic feet × 0.6232 equal British imperial gallons.
Cubic feet × 62.5 equal pounds avoirdupois.
Cubic feet × 0.028 equal tons (2000 lb.).
35.88 cubic feet equal 1 ton (2000 lb.).
Cylindrical feet × 0.02909 equal cubic yards.
Cylindrical feet × 5.875 equal U. S. gallons.
Cylindrical feet × 49.1 equal pounds avoirdupois.
Cylindrical feet × 4.895 equal British imperial gallons.
1 mile equals 5,280 lineal feet.
Lineal feet × 0.00019 equal miles.
Gallons, U. S., × 231 equal cubic inches.
Gallons, U. S., × 0.13368 equal cubic feet.
13.14 gallons equal 100 pounds avoirdupois.
268.8 gallons equal 1 ton (2000 lb.).
27.7 cubic inches equal 1 pound avoirdupois.

EQUIVALENTS OF LAND MEASUREMENTS

1 acre equals 209 feet square (nearly).
640 acres equal 1 section of land, or 1 square mile.
1 acre equals 220 feet by 198 feet, or 208.71 feet square, or 43,560 square feet.
1 square half-acre is 147.58 lineal feet at each side, or 110 feet by 198 feet.
1 square quarter-acre is 104.355 lineal feet at each side, or 55 feet by 198 feet.
1 circular acre is 235.504 feet in diameter.
1 circular half-acre is 166.257 feet in diameter.
1 circular quarter-acre is 117.252 feet in diameter.
Atmospheric pressure is to pounds per square inch as 34 is to 500.
Gallons, U. S., are to cubic feet as 800 is to 107.
Gallons, U. S., are to gallons British imperial as 6 is to 5.
Gallons, U. S., are to pounds of water as 3 is to 25.
Feet in water are to pounds per square inch as 34 is to 500.
Sea water averages 1.028 times as heavy as pure water and it contains about 3.44% of solids (of which 2.5% is sodium chloride).
The water of Great Salt Lake, Utah, is 1.170 times as heavy as pure water, and contains 22.42% of solids.
The water of the Dead Sea is 1.172 times as heavy as pure water.
The specific gravity of sea water is 1.03.

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Formula and Constants for Friction Loss in Dredge Discharge Pipes*

By H. BERRIDGE†

THE possibilities of hydraulic dredges have greatly increased of late, owing to the development of the cutter head on the suction pipe. Clay and other compact materials are now handled by this type of machine. The transport of the dredged materials through the pipe-line is an important factor in the question. I have investigated the figures given in the very complete reports of the Mississippi River Commission in the light of the pipe-friction formula given in W. C. Unwin's 'Hydraulics.'

Mr. Unwin says (p. 148): "At all velocities such as those with which the engineer has usually to deal, the flow of water in pipes is turbulent." The resistance originates in the irregularities in the surface of the pipe, producing eddy motions which fluid friction tends to still. "As the energy of an eddy is proportional to the square of its velocity and as this must have definite relation to the general velocity of translation of the stream, it is intelligible that the resistance varies nearly as the square of its velocity. In the strict sense there is no rational theory of turbulent motion but only empirical laws deduced from experiment" (p. 38).

The formula deduced by Mr. Unwin, after comparing a large number of experiments by different observers, is

$$\frac{h}{l} = \frac{m}{a^x}\,\frac{v^n}{2g}$$

where m is a constant depending on the surface of the pipe, x is a constant providing for variation in diameter of pipe (d), and n is a constant providing for variation in velocity of flow (v).

Converting the above into a logarithmic formula gives:

$$log\ h = n\ log\ v + log\ \frac{m}{d^x} + log\ \frac{l}{2g}$$

Plotting $log\ h$ as abscissas and $log\ v$ as ordinates gives a linear equation with a slope of n and an ordinate at the origin equal to

$$log\ \frac{m}{d^x} + log\ \frac{l}{2g}$$

Also, if m and x are constant, by plotting $log\ \frac{m}{d^x}$ as abscissas and $log\ d$ as ordinates the slope is x, and the distance from the origin to where the line cuts the horizontal axis is $log\ m$.

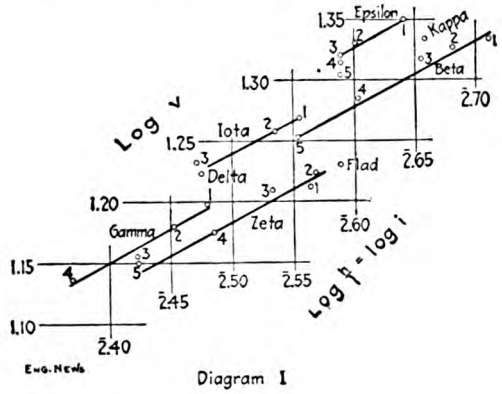

Diagram I

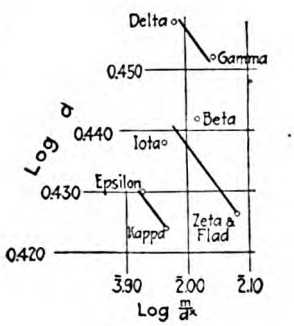

Diagram II

DIAGRAMS FOR DETERMINING CONSTANTS n AND x IN UNWIN'S EXPONENTIAL FORMULA, FROM OBSERVATIONS ON FRICTION LOSS IN DISCHARGE PIPES OF MISSISSIPPI DREDGES.

*Abstract from *Engineering News*, July 18, 1912.

†Port Engineer, Aden, Arabia.

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Mr. Unwin excluded high velocities of flow from the scope of his work, as the pressures in such cases have to be measured by mercury gauges, which present great difficulties, and his book is concerned with water supply only at low velocities.

In order to see if the formula were applicable to the velocities used for hydraulic dredging work, I used the diagrams showing the loss of head in the pipe-lines of the dredges Beta, Gamma, Delta, Epsilon, Zeta, Iota, Kappa, and Flad, as given in the paper of F. B. Maltby, read at the International Engineering Congress, 1904. The diameters of the discharge pipes on all the dredges varied only slightly. I thought it would be advantageous to plot $log\ i = log \frac{h}{l}$ instead of $log\ h$ as abscissas of the graph.

In Table I the values of i and v are given. They are plotted in Diagram I. It will be seen that Mr. Unwin's value of $n = 1.87$ for riveted iron pipe is very closely followed.

It should be noted that the values of h were obtained by mercury piezometers which showed considerable fluctuations.

The next step, finding x, does not give very good results in this case, as the range of d is so small. However, Mr. Unwin's value for

TABLE I. CONSTANT m FOR DREDGE DISCHARGE PIPES, AND CHECK CALCULATION OF FRICTION LOSS

(From Diagram I, n = 1.87; Diagram II, x = 1.39)

No. of observation	Mean velocity of flow ft. per sec., v	Loss of head, ft. water, h	Length of pipe, ft., l	Slope $\frac{h}{l}=i$	Constant m		Recalculation of friction head* h
Dredge "Beta"							
1	21.6	33.4	650	0.0514	0.0454		33.5
2	21.3	31.0	..	0.0479	0.0458		32.7
3	20.8	29.4	..	0.0452	0.0451	0.0461	31.2
4	19.3	26.0	..	0.0400	0.0459		27.2
5	17.9	23.2	..	0.0358	0.0483		23.1
Dredge "Gamma"							
1	15.9	18.1	600	0.0302	0.0490		16.1
2	15.3	17.0	..	0.0283	0.0473		15.5
3	14.4	15.9	..	0.0264	0.0496	0.0484	13.9
4	13.7	14.1	..	0.0234	0.0476		12.8
Dredge "Delta"							
1	16.7	18.7	625	0.0298	0.0435	0.0435	19.1
Dredge "Epsilon"							
1	22.4	10.2	235	0.0435	0.0330		13.5
2	21.4	9.35	..	0.0398	0.0327		12.4
3	21.1	9.07	..	0.0386	0.0327	0.0335	12.1
4	20.9	9.07	..	0.0386	0.0333		11.9
5	20.1	9.07	..	0.0386	0.0359		11.0
Dredge "Zeta"							
1	16.3	22.1	605	0.0366	0.0495		19.4
2	16.7	35.6	962	0.0370	0.0478		33.2
3	16.2	32.9	..	0.0341	0.0467	0.0462	30.6
4	15.0	29.5	..	0.0306	0.0476		26.4
5	14.2	25.5	..	0.0265	0.0465		23.8
Dredge "Iota"							
1	18.6	16.5	460	0.0324	0.0395		18.2
2	18.3	15.8	..	0.0309	0.0390	0.0388	17.6
3	17.1	13.6	..	0.0266	0.0380		15.6
Dredge "Kappa"							
1	21.77	8.5	187	0.0455	0.0359	0.0359	10.3
Dredge "Flad"							
1	17.00	17.6	450	0.0382	0.0480	0.0480	15.6
					Average value	0.0425	

*Based on n = 1.87
x = 1.39
m = 0.0425

TABLE II. VALUES OF CONSTANT n FOR GOOSENECKS

No. of observation	l	h (corrected for gravity)	$\frac{h}{l}=i$	v	n
Dredge "Iota"					
1	4.27	4.07	0.955	17.15	3.16
2	4.27	6.35	1.48	18.3	3.23
3	4.27	7.17	1.68	18.7	3.24
Dredge "Kappa"					
1	4.15	10.87	2.86	21.77	3.22
Dredge "Flad"					
1	4.19	4.07	0.97	16.50	3.09
				Average,	3.19

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riveted steel pipe, $x = 1.39$, gives a slope which is a fair mean of the observations.

Using this value of x, the value of m varies from 0.0359 to 0.0484 and has a mean of 0.0425, which approximates to Mr. Unwin's value for incrusted cast iron (0.0440). The usual value for riveted wrought iron is given as 0.0260, but it is easy to understand that the resistance offered by the flexible couplings and probably by some curvature of the pipes in the horizontal plane is responsible for the difference.

In order to show the results of using the values

$$n = 1.87$$
$$x = 1.39$$
$$m = 0.0425$$

the heads were re-calculated, using these values for the constants in the formula. The results are shown in the last column of Table I, and they may be compared with the actual heads shown in the third column of the same table.

Resistance of Reverse Bends. — In the dredges Iota, Kappa, and Flad a gooseneck or reverse bend was introduced at the stern of the vessel into the discharge-pipe line. This arrangement lifts the pipe above the water-level and is advantageous for altering the alignment of the discharge. The diagrams, however, show a considerable drop in head due to the resistance of these bends.

Dealing with experiments on the flow of water in bends, Mr. Unwin states that "the total resistance at a bend is made up of the skin resistance of a straight length of pipe of the same length as the bend, and an additional resistance due to the curvature, which is not a shock resistance, but merely an augmentation of the skin friction." To me, however, this opinion hardly seems consistent with the theory previously enunciated. I submit that surface friction of pipe cannot be very different in a bend from that in straight pipe, but that possibly increased eddy action is produced by the alternation in direction of the stream.

The resistance heads of the reversed bends in the discharge pipes of these three dredges was therefore analyzed in the same way as the heads in the straight pipe, using the variation of the formula

$$n \log v = \log \frac{h}{l} - \log \frac{m}{d^x} + \log 2g$$

If from Table I $\frac{m}{d^x}$ is assumed to be that found for the straight pipe, $n \log v$ can be calculated, and consequently n, as in Table II. The constant n is found to have a mean value of 3.19. The diagrams showing the heads are not, however, quite clear as to the corresponding velocities.

Laws of Heat Transmission Applied to Steam Plants*

By HENRY KREISINGER and WALTER T. RAY

APPLICATION of the principles of heat transmission offers an excellent opportunity for economic improvement in the steam-boiler as well as in steam-plant design. It seems feasible to increase the capacity of boilers several times; and at the same time, by properly arranging the heating surfaces in the boilers, to raise the efficiency perhaps several per cent. Increasing the capacity of boilers would reduce the first cost of the installation, and consequently less interest would have to be paid on a smaller investment. Increasing the efficiency would reduce the coal bill. Under such conditions power could be produced much more cheaply than it is at present.

Considering the high heat conductivity of metals, there is no reason why boilers could not be made to generate steam at three or four times the rate they do at present by simply forcing about three or four times the weight of gases over their heating surfaces. This may be considered a conservative statement, as much higher rates are possible than have been attained. It may at first seem that the power required to force such large quantities of gas through the boilers would be so great that the cost of installing and operating the 'draft' appliance would offset any gain from the increased capacity of the boiler.

*Abstract from Bulletin 18, Bureau of Mines.

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However, such is not the case. It is true that power required to push the gases through the boiler increases as the cube of the capacity the boiler develops, so that to triple the capacity of a boiler the power required to push the gases would have to be increased 3^3, or 27 fold; or, to quadruple the capacity the fan power would have to be 4^3, or 64 times as large as for single capacity. The one feature that makes high capacity† possible is the fact that the power really consumed in ordinary cases in pushing the gases through the boiler and furnace is so small that even after it is multiplied by 64 it still remains only a small fraction of that developed in the boiler. Distrust in the possibility of working steam boilers harder rests on past experience. Engineers are accustomed to hear that the steam consumption in mechanical-draft appliances is from 1 to 2% of the total steam generated by the boilers which are served by the appliances. With such extravagant 'draft' productions, of course large increase of boiler capacity would not be practicable. Thus, suppose that a fan producing 'draft' for a boiler battery at ordinary rates of steaming consumes 2% of the steam generated in the battery. If the capacity is to be quadrupled the fan would apparently have to do 4^3, or 64 times as much work as before. Since 4 times the capacity is developed, the steam consumed would be $\frac{64 \times 2}{4} = 32\%$ of the total steam generated at the quadrupled capacity. This, of course, is a considerable percentage, high enough to make any commercial consideration out of question.

However, a little more detailed investigation will show that with present mechanical-draft outfits about 90% of the energy that can be developed from the steam consumed in the fan engine is wasted in the crude inefficient engine, in the still cruder fan, and in the long leaky gas or air ducts having many sharp turns; and that only about 10% is actually expended in pushing the gases through the furnace and boiler. The power actually needed in foot-pounds is equal to the product of the pressure in pounds per square foot and cubic feet of air displaced; the following expression gives it in horse-power:

$$HP = \frac{pg}{33{,}000}$$

Where pressure in lb. per sq. ft. = p.
Cu. ft. gas displaced per minute = g.

In specific cases the power expended in pushing gases from the ash-pit to the base of the stack or to the uptake can be figured as shown in the following illustration: Assume that in a battery of boilers ordinarily developing 1000 boiler hp. the equivalent evaporation is 9 lb. of water per pound of dry coal of average quality, and that it takes 15 lb. of air to burn 1 lb. of dry coal; then the figures, where weight of coal burned per minute is W, weight of air used per minute is A, and where volume of air per minute is V, are:

$$W = \frac{1000 \times 34.5}{9 \times 60} = 63.9 \text{ lb.}$$
$$A = 63.9 \times 15 = 958.5 \text{ lb.}$$
$$V = 958.5 \times 13 = 12{,}460 \text{ cu. ft.}$$

Ordinarily the pressure-drop from ash-pit to uptake seldom exceeds 0.75 in. of water, but for convenience let the pressure-drop in this case be taken as 1 inch.

$$\text{One inch of water} = \frac{62}{12} = 5.16 \text{ lb. per sq. ft.}$$

$$\text{Horse-power} = \frac{12{,}460 \times 5.16}{33{,}000} = 1.95.$$

Now, according to the cube law, if the capacity of this battery is to be quadrupled, the power needed to move the gases would be 4^3, or 64 times 1.95, which is approximately 125 hp. Surely in a unit of this size one engine brake horse-power ought to be produced with one boiler horse-power, and fans having an efficiency of 75% can be built. With such outfits the consumption of steam for the quadruple capacity would then be

$$\frac{125}{4000 \times 0.75} = 4.2\%$$ of the total steam generated.

When one considers that in big power-

†Ray, W. T., and Kreisinger, Henry, 'The Significance of Drafts in Steam-Boiler Practice.' Bull. 21, Bureau of Mines.

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stations' power is produced in large electrical units at about half the steam consumption assumed above, and also remembers that the fans could be driven electrically, the quadruple capacity appears commercially feasible—especially if by proper arrangement of the heating surfaces the efficiency of the boilers is increased.

If one considers the sizes of fans usually seen in power-plants at present, he may perhaps make the objection that if the capacity of boilers were quadrupled the fans would be so large that they might take up the greater part of the space saved by making the boilers do more work. There is, however, no substantial reason for fearing such conditions. The fans used at present are unduly large because of their low efficiency; in different constructions the efficiency ranges from 80 down to 10%, and in most is perhaps much closer to 10 than 80%. Fast-running fans of large capacity and high efficiency are now being put on the market. Such fans could be easily placed under or above the boiler they were to serve without being conspicuous on account of their size.

In designing a steam-generating apparatus to produce steam at high rates, probably the greatest difficulties will be met in the furnace. To produce four times the weight of hot gas, four times the weight of coal must be burned in the same time. To burn coal thus rapidly without large losses through incomplete combustion of gases and tar vapors, driven off from the soft coals upon heating, and losses in sparks—losses which always accompany the high capacity of the locomotive and torpedo-boat boiler—the furnace would have to be the larger part of the steaming apparatus.

To prevent the escape of unburned gases and tar vapors, the principle of slow heating should be used in stoking the coal, in order to avoid the distillation of heavy hydrocarbons which are difficult to burn. Combustion space should be provided in which to burn the lighter and more quickly burning compounds.

In the locomotive and torpedo-boat boiler the grates are comparatively small, so that in order to force a large quantity of gases through the fuel bed the velocity of the gases must be high. This high velocity lifts small particles of burning coal from the fuel bed and carries them through the boiler. To avoid the loss from sparks in stationary boilers, the velocity of the gases through the fuel bed should be kept so low as not to start the sparks on their way to the stack. This end can be attained by increasing the grate area. The increase in the grate area will also reduce the power needed to push the gases through the fuel bed. The velocity through the boiler itself should be high, so as to carry through the boiler any solid particles that might settle on the heating surface. If the gases flow faster through the boiler than through the fuel bed, it is obvious that any solid substance that has been light enough to be lifted from the fuel bed will surely be carried through the boiler by the higher velocity. To burn four times the weight of coal on double the grate area would require much less pressure-drop through the fuel bed than if it had to be done on the present small grates. Increasing the grate area would reduce the fan work considerably.

A few years ago the gas-engine apparently threatened to displace the steam-engine and even the steam-turbine, wherever mechanically feasible; that is, wherever real estate was cheap. It has not done so, however, and if one seeks the reason why it has not, he has only to study some figures in a paper by William L. Abbott, chief operating engineer of the Commonwealth-Edison Co. of Chicago. Mr. Abbott states that of the total operating revenue received by large central-station companies, 50% goes out for 'fixed charges' consisting of interest or dividends on investment, sinking fund, or depreciation, taxes, and insurance; 30% for operating expenses of all kinds whatsoever, and 20% for general expenses, including salaries of general officers, advertising, and rentals. Of the 30% spent for operating expenses, 20% goes for coal; in other words, only 6% of the company's gross operating income goes for fuel. Mr. Abbott specifically states that the fuel saving attained by a gas-engine plant would be more than overcome by the heavier fixed charges on such a plant; especially would this hold if the heavier labor costs in gas-engine plants using producers are taken into consideration. Now it is easy to see that a gas-engine plant that would save half the coal (an improbable attainment) would save only 3% of the gross operating revenue, and that the increased labor costs alone might approach the saving, not to consider the added bond

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interest. The following figures of the cost of installation of steam-turbine plants and of producer-gas engine plants of large capacities are taken from a chart compiled by Edwin D. Dreyfus.

COST OF INSTALLATION OF STEAM-TURBINE AND OF PRODUCER-GAS ENGINE PLANTS.

Total plant capacity installed (kw.).....	Cost of steam-turbine plant per kw.....	Cost of producer-gas engine plant per kw.
4,000	$75.00	$110.00
8,000	65.00	104.00
12,000	58.00	102.00
16,000	53.00	100.00
20,000	49.00	99.00
24,000	47.00	98.50
28,000	46.00	98.30

The cost of labor Dreyfus gives as 19 to 13% of the total power-plant charge in the steam plant and from 23 to 20% in the gas-producer plant. The above status of the comparison is present-day. It has been repeatedly pointed out that there are bright prospects of getting two or three and perhaps four times the amount of steam from a given boiler-house investment at a higher efficiency than is usual at present. If steam power-house builders should put as much extra money into air pre-heaters, fans, and economizers as the advocates of gas-engines desire put into gas installations, the additional equipment would work some surprises; whether the greater investment would be sound commercial economy in most cases, we do not undertake to say.

It is well known that in modern turbine power-plants the boiler-room is the costly portion; if it be assumed (probably safely for our purpose) that only one-fourth of an electricity-supply company's money is in its power-houses, and that three-fifths of this latter investment is in the boiler-rooms, then to reduce the boiler-room investment only one-half would reduce the total bond interest 7.5%, a liberal dividend on the average amount of capital stock—and it must be borne in mind that such companies always will be run for the benefit of the stockholders.

By applying the principles of heat transmission, it would be possible to design with fair accuracy a boiler for any desired efficiency. It has been shown that the efficiency of a boiler can be increased by increasing the length of gas path or by reducing the cross-section of the gas passages. By the latter is meant the cross-section of each elementary stream and not the sum of all of them. In other words, the reduction of cross-section must reduce the 'hydraulic mean depth' if the efficiency is to be increased. The 'hydraulic mean depth' is the quotient of the area of the cross-section of the gas stream divided by the perimeter formed by the heating surface of the boiler and touched by the gases. Thus, if the size of the tubes in fire-tube boilers is reduced, the area is decreased in proportion to the square of the diameter of the tubes, whereas the perimeter is reduced only in proportion to the first power of the diameter; therefore the quotient, or the hydraulic mean depth decreases in proportion to the diameter of the tube. If, however, the size of tubes is kept, but their number is reduced, then the area decreases at the same rate as the perimeter, and therefore the 'hydraulic mean depth' remains constant.

In a similar way, the effective reduction in the cross-section of the gas stream in a water-tube boiler is attained only by placing the water tubes closer together and not by reducing the number of tubes or baffling the boiler. So that, to be effective, a reduction in cross-section of the gas stream must always be accompanied by a reduction of 'hydraulic mean depth,' or the mean distance of the particles of gas from the dry surface.

It has been shown that for fire-tube boilers the relation between the true boiler efficiency and the length and diameter of the tubes can be approximatly expressed by the equation

$$E = 1 - e^{-\frac{cl}{r}}.$$

The relations can be shown better by the graphical representation of this equation given in Fig. 1 and 2. These two charts enable anyone to solve for the unknown value when the other two are given, without complicated calculation. Both figures

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are based on the dimensions and efficiency of the locomotive boiler tested by the U. S. Geological Survey at the Seaboard Air Line shops, Portsmouth, Virginia. The tubes of this boiler were 2 in. diam. by 14 ft. long, and the true boiler efficiency was approximately 80%. The values obtained from these figures are more particularly adaptable to locomotive boilers.

Each curve in Fig. 1 shows how the efficiency varies with the length of the tubes when the diameter remains at the constant value indicated on each curve. Thus, on the curve of 2-in. diam. when the length, given at the base of the figure, is 14 ft., the true boiler efficiency is 80%, the starting point. Now, if one wishes to know how long tubes of the same diameter would have to be to give a true boiler efficiency of 90%, he should follow the curve of 2-in. diam. until he reaches the horizontal line of 90%, and from the point of intersection drop a vertical line to the scale at the foot of the chart; this scale shows that the length must be 20 ft. Most horizontal multi-tubular boilers have tubes 3.5 in. diam. and about 16 ft. long; what is their true boiler efficiency? Follow the curve of 3.5-in. diam. until the vertical line starting from the point of 16-ft. length is reached; then from the intersection follow the horizontal line to the efficiency scale on the left. This scale indicates the efficiency of the multi-tubular boiler to be about 65%. Suppose a boiler designer wishes to design a boiler that will have a true boiler efficiency of 95%, and wants to use tubes of 1-in. diam, how long will the tubes have to be? Follow the curve of 1-in. diam. until the efficiency line of 95% is reached; the imaginary vertical line indicates that the length of the tubes must be about 12.75 feet.

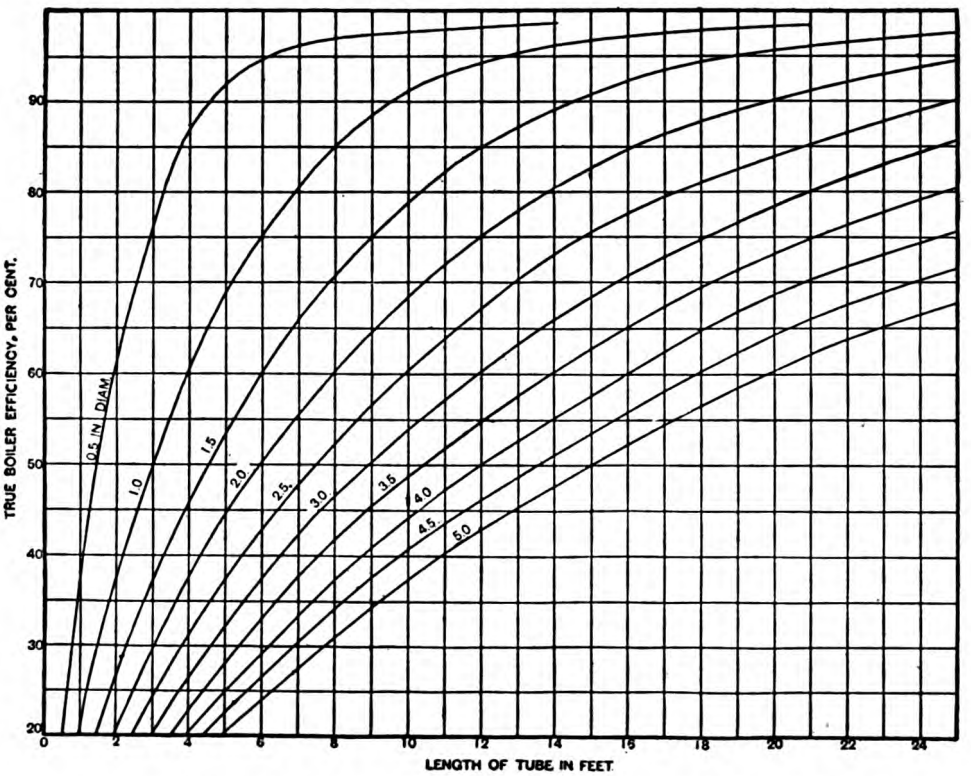

FIG. 1. RELATION BETWEEN THE TRUE BOILER EFFICIENCY AND THE LENGTH OF FLUES.

The curves of Fig. 2 give the relation between the true boiler efficiency and the diameter of tubes for constant lengths indicated on each curve. This chart can be used to advantage to find any one of the three factors when the other two are given, but it

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was particularly designed for finding the diameter of the tubes required for any given length and efficiency. Thus, suppose a boiler designer has to design a special boiler having 90% efficiency and the place where the boiler is set up is such that the tubes cannot be more than 10 ft. long, what size tubes should the designer use? Take the curve of constant length of 10 ft. and follow it to the intersection point with the horizontal line of 90% efficiency; from this point drop a vertical line to the scale at the foot of the chart. The diameter is found to be a little over 1 inch.

Again, suppose that it is desirable to lengthen by 6 ft. the grate and combustion space of a locomotive boiler without increasing the total length of the locomotive. At the same time it is required that the efficiency should be raised about 5%. Under such conditions the necessary furnace length can be gained by shortening the tube part of the boiler by 6 ft. and by decreasing the diameter of the tubes. At present the length of the tubes is 14 ft. and the diameter is 2 in.; the tube length of the modified boiler will then be 8 ft. What should be the diameter of tubes if the efficiency is to be raised from 80 to about 85%? To solve this problem, take the curve of constant length of 8 ft. and follow it to its intersection point with the horizontal line of 85% efficiency; this intersection point comes very close on the vertical line of 1 in. diam. For the modified boiler, then, the tubes should be 8 ft. long and 1 in. diameter.

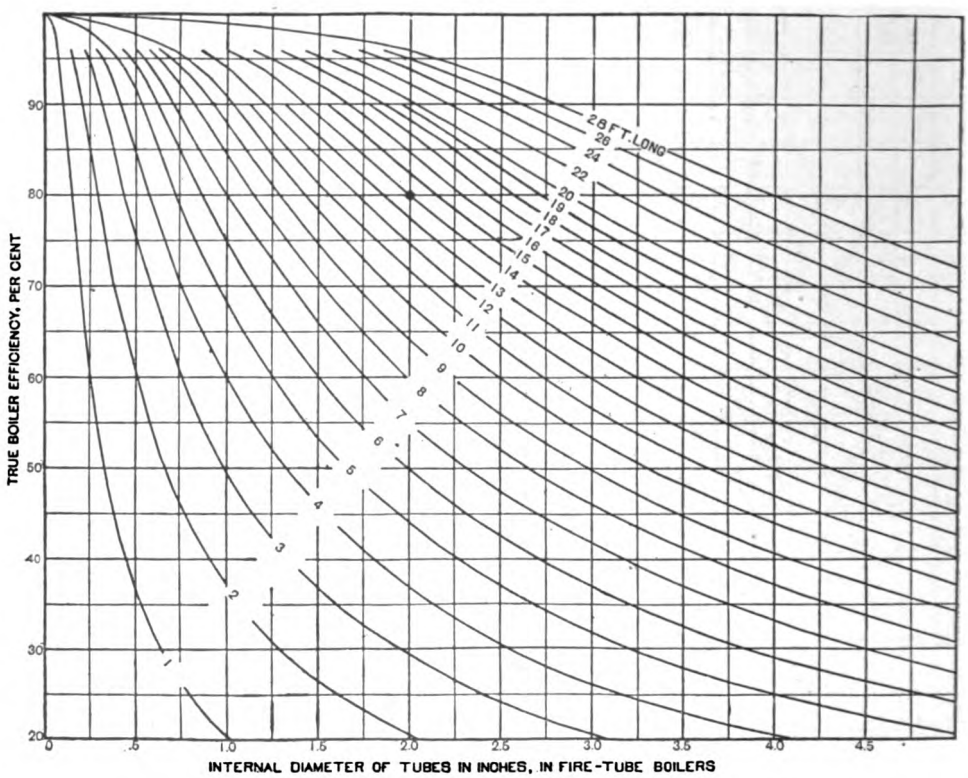

FIG. 2. RELATION BETWEEN THE TRUE BOILER E FFICIENCY AND THE DIAMETER OF FLUES.

Although the authors are confident that the relations shown by the curves of Fig. 1 and 2 are fairly close to the truth, nevertheless, they wish to emphasize that the curves are presented only to illustrate how the dimensions of fire-tube boilers could be easily determined with mathematical accuracy for any desired true boiler efficiency, if the exact relations of these sizes of tubes were first determined by experiment.

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California's State Highway*

By AUSTIN B. FLETCHER†

FROM time to time since January 1, 1912, the California State Highway Commission has ordered surveys on the various routes as fast as general routing problems were settled. In some cases reconnaissances only were ordered. In others, two or more surveys were ordered between objective points to determine which was the best. At the present time 31 survey parties are engaged in such work, and the surveys are proceeding as rapidly as careful work will permit. The survey notes go from the field to the division offices, where the plans are made by the draftsmen. Ultimately they

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are sent to the headquarters at Sacramento with the reports of the division engineers for revision and correction when necessary. To this date approximately 1500 miles of road survey has been ordered by the commission, and of this total nearly 800 miles of field work has been completed, and more than 200 miles in addition is in process. The survey orders were carefully distributed throughout the seven divisions, and no portion of the state is being neglected. The surveys ordered and made are considered as tentative only, and when necessary the lines are changed to conform to new conditions which arise, but as a rule the commission has given earnest consideration to the needs of the state before ordering the surveys. Even in the flat country, such surveys cost too much money to be ordered at random.

In brief, the standard road which the commission proposes to build will have the following principal characteristics:

1. A right-of-way not less than 60 ft. in width where it is reasonably possible, and as direct between objective points as is consistently possible.

2. Gradients not exceeding 7%, even in the mountainous parts of the state.

3. Curves as open as possible, and in no cases less than 50 ft. in radius.

4. As many culverts of sufficient capacity as are needed to take care of surface and underground water.

5. A traveled way under ordinary conditions not less than 21 ft. in width, and in the mountains not less than 16 ft. wide, with the centre paved or surfaced so as to be hard and smooth under all climatic conditions at all times of the year, the width of surfacing to be in general 15 feet.

6. Smoothly graded roadsides, reserved for future tree planting.

For the main roads of the system the choice for surfacing seems to lie between the so-called oil macadam type and a concrete road with a bituminous surface, the latter being considerably more expensive than the former, but much more desirable as concerns quality and permanency. It is evident that neither type can be adopted for general use unless the cost of the materials and the freight charges for transporting them are reduced to the lowest point possible. It seems apparent that not less than 2700 miles of state highway must be built to comply with the provisions of the State Highways Act. Of this mileage it is possible that one-third, or 900 miles, will be in the mountains and will require no surfacing other than local gravel, and that 1800 miles will have to be surfaced with materials more or less expensive.

There are now 37½ miles of state highway under contract in widely separated parts of the state, and 58 miles more are now under advisement, the bids to be opened during the last week of August. Of the roads under contract, 13 miles are in Mendocino county, south of Hopland, where the work consists in re-locating and grading the road over the mountains, the rate of grade being reduced from a present maximum of over 12% to a 7% minimum. Five and four-tenths miles are in San Mateo county, where sheet asphalt 24 ft. wide on a 5-in. concrete base is being laid. Nine miles are in Yuba county, where the road has been entirely re-located, and oiled macadam 15 ft. wide is to be laid.

On all the roads now advertised and awaiting contract, it is proposed to use a hydraulic cement concrete base 15 ft. wide, covered with a thin surface of a bituminous mixture. Whether or not much additional work of this character may be done depends largely upon the cement manufacturers. It is probable that they will make some reduction in the cement price to induce the commission to adopt the concrete base for its standard type of construction. Whether the reduction in price will be sufficient to permit of so general a use of concrete is not yet determined.

The counties have generously agreed to furnish such rights-of-way as are needed for re-locating the roads, and the commission expects that none of the bridges of the state which are more than 20 ft. in span will have to be built with money from the highway fund. Thus far no county has refused to reconstruct such bridges or to build new ones when the commission has made the request. Of the 31 survey parties now at work, 18 are on the coast highway between Willits on the north and San Diego on the south. Every effort is being made to have the main state highway routes completed before the exposition at San Francisco opens its doors in 1915.

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Company Reports

American Telephone & Telegraph Co.—The annual report of the American Telephone & Telegraph Co. has been issued by Theodore N. Vail, president. This company owns and controls what is known as the Bell system in the United States. The total number of stations for 1911 was 6,632,625, which is an increase of 749,906 as compared with the previous year; 2,158,454 of these were operated by local independent companies or associations having sub-license or connection contracts. The toll lines have now reached 70,000 localities, at which also in nearly every case a telegraph business is done. General statistics show the remarkable extent to which the telephone is now used. The total mileage of wire in use for exchange and toll service was $12,932,615 miles, of which practically 10% represents the increase for the year 1911. These figures do not include the mileage of wire operated by connecting companies. The daily average of toll connections, including long-distance but not including connecting companies, was 645,000. The total daily average, including exchange connections, for 1911 reached 24,129,000. Additions to plant and real estate for the year totaled $55,660,738. Comparison of earnings and expenses of 1910 and 1911 and balance sheets are as follows:

COMPARISON OF EARNINGS AND EXPENSES, 1910 AND 1911

	1910.	1911.
Gross earnings...	$165,612,881	$179,477,998
Expenses:		
Operation	$ 54,235,449	$ 60,085,425
Current maintenance	25,763,082	30,184,522
Depreciation ...	26,264,927	28,655,832
Taxes	8,355,015	8,965,922
Total expenses	$114,618,473	$127,891,701
Net earnings.....	$ 50,994,408	$ 51,586,297
Deduct interest...	11,556,864	13,610,860
Bal. net profits..	$ 39,437,544	$ 37,975,437
Deduct dividends paid	25,160,786	25,966,876
Surplus earnings.	$ 14,276,758	$ 12,008,561

COMBINED BALANCE SHEETS, 1910 AND 1911

Assets:	Dec. 31, 1910.	Dec. 31, 1911.
Contracts and licenses	$ 2,943,381	$ 2,943,381
Telephone plant	610,999,964	666,660,702
Supplies, tools..	20,987,551	20,749,568
Receivables	26,077,802	32,916,127
Cash	27,548,933	41,878,140
Stocks, bonds...	64,766,089	66,777,231
Total	$753,323,720	$831,925,149
Liabilities:		
Capital stock...	$344,645,430	$379,727,832
Funded debts...	224,791,696	241,032,822
Bills payable...	42,566,943	41,198,431
Accounts payable	21,721,125	23,382,438
Total outstanding obligations	$633,725,194	$685,341,523
Surplus and reserves	119,598,526	146,583,626
Total	$753,323,720	$831,925,149

All duplications, including interest, dividends, and other payments to American Telephone & Telegraph Co. by associated holding and operating companies, excluded.

Union Pacific and *Southern Pacific* ended the first 11 months of the current year now closing with losses in net earnings of $3,891,262 and $2,912,163 respectively. May contributed further losses to those of the months preceding, Union reporting a decline in net of $437,648 and Southern of $112,231. Net of Union Pacific has gone down over 10% per annum since 1910 and Southern Pacific's an average of about 8%. Below are compared results for the 11 months of the current year, with the 'big' 1910 year and the poor 1908 year:

Union.	1912.	1910.	1908.
Gross .	$79,071,682	$82,719,140	$69,908,043
Net ...	36,710,673	43,601,283	37,555,938
Southern.			
Gross .	$120,984,339	$123,728,193	$110,124,419
Net ...	36,710,673	43,601,283	37,555,938

Union Pacific's net earnings for the 11 months as shown in the above table are 11.9% less than for the same period of 1911, and 1911 figures were 11.8% less than the 1910 total shown above. Similarly, Southern Pacific's 11 months' net has decreased

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7.4 and 9.1% respectively in 1912 and 1911. Earnings this year will result in per share profits of approximately 14% on Union Pacific, compared with 16.6% in last year, and of approximately 9.2% for Southern Pacific, against 9.5 a year ago. *(Boston News Bureau.)*

Southern California Edison Co.—Earnings of this company for the first six months of 1912 show large increases in both gross and net. For the year ended May 31, 1912, $685,000 was charged to depreciation reserve, while for the six months ended June 30, 1912, the company charged $305,000 to depreciation.

The company owns and operates hydro-electric and steam-electric generating stations and gas plants. It has a distributing system of 208 miles of high-tension transmission lines and 410 miles of power circuits, covering Los Angeles, Pasadena, Highlands, Redlands, and many other southern California towns, with gas plants at Santa Monica, Pomona, and San Pedro. Its total electric generating capacity is about 75,000 hp. Its largest plant is on Kern river, 116 miles from Los Angeles. For the first six months of 1912 the company showed gross earnings of $2,099,762, an increase of $332,199 over the first six months of 1911. Net earnings were $1,001,537, an increase of $108,055. Bond interest for the six months was $359,689, and $305,000 was charged off for depreciation, leaving the surplus for the six months $336,849, an increase of $54,763 over that for the first six months of 1911. The company has $7,900,000 common and $4,000,000 5% preferred stock with $14,768,000 bonds outstanding. The California Railroad Commission has authorized the company to issue $4,117,000 additional general mortgage bonds. These are to be exchanged for an equal amount of the underlying bonds.

For the twelve months ended May 31, 1905, the gross earnings of the company were $1,062,824, while for the twelve months ended May 31, 1912, the gross earnings were $4,011,669. On May 31, 1912, the company was furnishing current equivalent to 1,309,022 50-candlepower incandescent lamps; it had 71,534 electric meters connected, with 5481 electric motors of 77,885 hp. Surplus earnings of the company for the year ended May 31, 1912, before depreciation charges were made, were $1,361,077. The dividends on the preferred stock for the twelve months were $200,000, leaving a balance of $1,161,000, or about 13% on the $7,900,000 of common stock. The company charged off $685,000 for depreciation, which, after preferred dividends, left $476,077 for the common stock, or at the rate of a little over 6% on the stock. The company pays 1¼% quarterly dividends on its common stock.

The Portland Railway, Light & Power Co. reports for June and six months as follows:

June gross..	$ 582,964	$554,767	Inc. $28,197
June net ...	305,282	292,595	Inc. 12,687
June surplus	156,242	163,440	Dec. 7,198
Six mo. gross	3,252,617	3,114,812	Inc. 137,805
Six mo. net..	1,605,280	1,611,676	Dec. 5,396
Six mo. surp.	734,104	867,852	Dec.133,748

The Northern California Power Co., Consolidated, reports for July as follows:

Gross earnings	$65,817.77
Operating and general expenses..	17,348.29
Net earnings	$48,469.48
Maintenance and depreciation reserve	9,872.66
Total	$38,596.82
Bond interest	28,288.25
Available for surplus and dividends	$10,308.57

Great Western Power Co. reports for the first six months of 1912, as compared to the same months in 1911, as follows:

	1911.	1912.	Inc.	%
Gross rev..	$967,232	$1,091,830	$124,598	+12.8
Op't'g exp..	395,176	429,062	33,884	+ 8.5
Net earn'gs.	572,056	662,769	90,713	+15.8

The Standard Gas & Electric Co., the holding corporation for securities of the Northern States Power, Western Gas & Electric, and a number of other properties managed by H. M. Byllesby & Co., reports earnings for the twelve months ended June 30, 1912, as follows:

Gross earnings	$1,919,052
Net earnings	1,881,353
Interest charges	469,557
Balance for stocks	1,411,795
Preferred dividends	684,894
Balance for common	726,900
Per cent earned on common stock.	7.8

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Book Reviews

HUMAN FACTOR IN WORKS MANAGEMENT. By James Hartness. Pp. 159. Index. McGraw-Hill Book Co., New York. For sale by the *Mining and Scientific Press*, San Francisco, California. Price $1.50.

To a man who has been vainly trying to assimilate the new doctrines of motion study, planning rooms, slide-rule calculations of cutting-speeds involving countless variable factors, and the numerous other new ideas embraced under the general heading of 'scientific management,' Mr. Hartness' book is as refreshing as a cold shower on Monday morning. The author frankly calls himself a reactionary, and justifies his views by comparing the advocates of the strenuous life for everybody to the boy who gave his grandmother a trumpet and drum for a Christmas present. The psychological aspect of the workman himself is the theme that is followed throughout, and is presented in an easy, epigrammatic style that is not only instructive but exceptionally entertaining. It seems that, in the vernacular, we are 'off on the wrong foot' and have been so eager to assume that new ideas must necessarily be good, that we have neglected that important characteristic of mankind that the author calls the 'inertia of habit.' Mr. Hartness emphasizes the fact that any change in the established practice in a manufacturing establishment is disastrous, not only as far as cost is concerned, but on account of the effect on the men themselves. Managers must weigh carefully the pros and cons of any contemplated change before they can decide that the game is worth the candle. The best use of present means will in nearly every case give a comfortable assurance of continued dividends and contented workmen, while the chaos resulting from the introduction of new methods, however correct in theory, results in disorganization from which recovery is costly and difficult. Mr. Hartness is not altogether opposed to progress, however, as his well known business success will testify. He is rather inclined to favor a progressive conservatism that calls for an application of the soft pedal until the progressiveness of today becomes the conservatism of tomorrow. Specialization is urged to even a greater extent than at present practised. Habits are to be cultivated, provided they are of the right kind, on the theory that the man who leaves his work at night with the least amount of mental or physical weariness is he who has spent the day at a routine task calling for no material amount of mental or physical effort.

The square posts that are occupying round holes and chafing at the bad fit are objects of commiseration that place a responsibility upon the manager to keep shifting the pegs until each employee is engaged either upon a congenial task or is hunting a new job. Factory managers will appreciate the sound common sense that appears in every line, and some of them might well present copies of this book to the non-technical members of their board of directors, who have obtained their knowledge of scientific management from pictorial magazines.

REINFORCED CONCRETE CONSTRUCTION. By George A. Hool. 254 pp. Index. McGraw Hill Book Co., New York. For sale by the *Mining and Scientific Press*, San Francisco, California. Price $2.50.

This is the first volume of a series of three works on the general subject of reinforced concrete construction and covers the fundamentals. The second volume, to appear later, will deal with detail design of retaining walls and buildings, while the third will cover the detailed design of bridges and miscellaneous structures. The entire series form a part of the correspondence course in reinforced concrete construction offered by the extension division of the University of Wisconsin, at which the author is assistant professor of structural engineering. Mr. Hool's experience as a teacher has given him abundant qualification for the preparation of textbooks for home study. His language is clear, concise, and free from unnecessary technical terms that are so confusing to elementary students. The subject-matter is divided into nine chapters covering concrete, steel, and their combination; the theory and design of rectangular beams, slabs, cross-beams and girder columns, together with tables, diagrams, and the study of bending and direct stresses. It is not infrequent for engineers in the active practice of their profession to find occasion when a little brushing up on fundamentals is necessary, and Mr. Hool's works will be a valuable addition to any technical library.

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Engineering Bonds

*Tax exempt in California.
†Legal investment for savings banks in California.
‡Available as security for deposit of state, county, and municipal funds and postal savings deposits.

THE SOUTHERN CALIFORNIA UTILITIES CO. is about to issue $10,000,000 of 25-year 5% bonds and $10,000,000 in common stock. The company is said to have physical assets valued at $43,000,000 and to have a present earning power of $100,000 per year. A portion of the common stock has been issued in exchange for properties, including those of the Lake Hemet Land & Water Co. The assets are made up principally of land, water rights, and potential power development possibilities. The San Diego, Riverside, and Los Angeles Railroad Co., which is affiliated with the Utilities company, in addition to its $8,000,000 authorized bonds has issued $8,000,000 in common stock. A steam railroad will be constructed which, under its charter, may be converted to an electric system at some later date. The road is intended primarily for the development of the land held by the Utilities company.

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*†THE ORO ELECTRIC CORPORATION has issued $10,000,000 of 6% first mortgage sinking fund gold bonds in denominations of $1000 each, dated October 1, 1911, and due October 1, 1951. The Oro Electric Corporation controls all the property and the subsidiary companies of the Oro Water, Light & Power Co. in, and in the vicinity of the town of Oroville, Butte county, California. In addition to owning all of the electric, gas, and water business in Oroville and vicinity, the company has valuable rights in dredging properties in the vicinity of Oroville and Stockton, water rights in Humbug valley, Butte creek, Deer creek, Mill creek, Grizzly creek, Yellow creek, and Soda creek, in Plumas, Tehama, and Butte counties. The company is at present operating two hydro-electric power plants in the Sierra Nevada mountains, of 4000-hp. capacity, in connection with about 50 miles of distribution system. It is proposed ultimately to develop the power capacity to a maximum of about 40,000 hp. The first unit, which is to be installed immediately, will be about 26,000 hp. The development work to be inaugurated immediately, provides for the improvement of water rights in Humbug valley, Butte creek, Mill creek, Grizzly creek, and Soda creek. Approximately 40 miles above the present plant at the point where Yellow creek empties into the north fork of the Feather river, a static head of 1905 ft. is obtained. A storage reservoir of three billion cubic feet capacity is to be built just above this point in Humbug valley. While the ultimate possible development at this point is about 53,000 hp., the installation about to be commenced will have a capacity of 26,000 hp. The storage area is 5000 ft. above sea-level and its capacity will carry a maximum power development over a period of three of the driest years on record in California, according to annual precipitation statistics and careful measurements made covering a period of many years. A power-transmission line erected on steel poles is to be installed, with Oakland as its ultimate destination, although all of the power produced by the first installation will be distributed within the intervening territory.

CAPITALIZATION

Stock:	Authorized.	Issued.
Preferred 6%	$3,500,000	$3,500,000
Common	6,500,000	6,500,000
Bonds:		
First mortgage Oro Electric Corporation 6% sinking fund gold bonds	10,000,000	.....

EARNINGS

The following is the income statement for the year ended December 31, 1911:

Gross earnings	$776,041
Operating expenses and taxes	415,347
Net earnings	$360,694
Interest charges	38,374
Surplus above interest charges	322,320

Upon the completion of the first installation, the annual earnings are conservatively estimated as follows:

Gross earnings	$1,056,041
Operating expenses and taxes	490,347
Net earnings	$565,694
Interest charges	228,000
Surplus above interest charges	$337,694

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Engineering News

Power, Gas, and Electricity

Los Angeles. — The Southern California Gas Co. has applied to the Railroad Commission for a franchise to build and maintain a pipe-line connecting Vernon, Huntington Park, Compton, and Long Beach. E. F. Scattergood, electrical engineer of the Los Angeles aqueduct, has recommended the construction of a complete electric light and power-distributing system for use in connection with the hydro-electric power-plant now under construction for the Los Angeles aqueduct at San Francisquito canyon. The Pelton Water Wheel Co. of New York has been awarded contract for the penstocks at a price of $230,000 delivered at Los Angeles. Contract for the riveted sections and the siphons over Bee canyon has been awarded to the Treadwell Construction Co. of Midland, Pennsylvania. The Midway Gas Co. has applied to the City Council for a modification of the gas ordinance permitting it to distribute and sell natural gas in the city of Los Angeles. It has been announced that the first 12-in. line from the Midway field, 115 miles distant, will be completed about October 1. The Southern California Gas Co.'s distribution system will be utilized.

San Diego.—The San Diego Con. Gas & Electric Co. has applied to the Railroad Commission for permission to issue bonds to the amount of $250,000. Part of these funds will be used to reimburse the company for capital expenditures and the balance for plant expenses.

San Francisco. — The Central California Gas Co. has asked permission of the Railroad Commission to exercise franchise rights acquired to distribute gas in Porterville and Lindsay, Tulare county. Statement of the Standard Gas & Electric Co. for the twelve months ended June 30, 1912, shows gross earnings of $1,919,000, with a surplus for the common stock of $726,900, or more than 8% for the year.

Placerville.—The Western States Gas & Electric Co. will construct a power line from Placerville to Camino.

Richmond.—Southern Pacific Co. has commenced extension of its electric surburban service to Richmond. B. W. Perrin Co. has the contract. A total of $1,085,000 will be expended.

Cleveland, Ohio.—The Telluride Power Co., (J. R. Nutt, president; P. B. Sawyer, vice-president and general manager) is contemplating improvements in its plant to cost approximately $2,500,000. The Bear Lake reservoir and irrigating ditches leading therefrom are to be completed. A reservoir will be built at Soda Point, near Soda Springs, Idaho, to supply the peak of the Grace, Idaho, power-plant. An 8-ft. diam. steel pipe-line 6½ miles long will be built from this point to the Grace generating station to increase its capacity by about 21,000 hp. A dam will be built to impound the tail-waters from the Grace station, to have a capacity of about 150,000 acre-feet. From this point conduits will be built to another generating station below Oneida Narrows, which will furnish an additional 25,000 hp. Improvements will also be made in the Telluride plant in Logan canyon and in Provo canyon, and further improvements in Colorado.

Durango, Mexico.—The Durango Hydro-Electric Light & Power Co. will install a plant on El Salto property, about 42 miles west of Durango. Six hundred ninety-two feet fall is obtained in a pipe-line 1400 ft. long. Two storage reservoirs are to be constructed, and 1000 hp. will be developed which will be used for municipal and other purposes in the city of Durango.

Topia, Mexico.—The Topia Mining Co. will install a hydro-electric power-plant to work under a head of 1800 ft. for operating its mill.

Irrigation and Water Supply

Los Angeles.—Specifications for the new water works system for San Pedro, Wilmington, and Terminal Island prepared by William Mulholland, chief engineer, have been accepted by the Public Service Commission. In addition to necessary piping and fittings, a 4,000,000-gal. pumping engine and 1500-cu. ft. air-compressor and two 250-hp. boilers will be installed. The approximate cost has been estimated at $160,000.

Glendora.—The water board has been notified that the town of Glendora will raise $100,000 for financing a water-supply system.

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Estimates will be prepared by William Mulholland, chief engineer of the Los Angeles aqueduct.

San Diego.—A proposal to issue $2,500,000 in bonds for the purpose of a municipal water-supply has been approved by a vote of the people.

Sacramento.—Commissioner Wilder has recommended to the Board of Public Works that $25,000 be appropriated for a new pump for the city water works and $11,000 for the extension of the fire-alarm system.

Stockton.—The Turlock Garden & Land Co. is about to commence reclamation of 5000 acres of land along the San Joaquin river in San Joaquin county. The total amount to be expended is approximately $100,000.

Woodland.—The Yolo Water & Power Co. has commenced surveys for its new irrigation system. Thomas Prather, Mechanics Institute building, San Francisco, is president. Sufficient water is to be developed for irrigating 50,000 acres of land.

Oroville.—The Northern Electric Railroad Co. is prospecting ground with a Keystone drill for the purpose of developing a number of wells for irrigating purposes.

College City (Colusa county).—W. T. Wilkins has been awarded contract to move 130,000 cu. yd. of earth for the construction of a levee in reclamation district No. 70 near Meridian.

Reclamation

Progress of work of the U. S. R. S. projects during July 1912 is as follows: *Arizona.*—Salt River project, 93.8% completed. *Arizona-California.*—Yuma project, 74% completed. *California.*—Orland project, 84.5% completed. *Colorado.*—Grand Valley project, preliminary work. Uncompahgre Valley project, 55.1% completed. *Idaho.*—Boise project (exclusive of Arrowrock reservoir), 98% completed; Arrowrock reservoir, 20% completed; Minidoka project (gravity unit), 88.5% completed; South Side pumping unit, 92% completed. *Montana.*—Blackfeet project (Two Medicine unit), 64.9% completed; Badger-Fisher unit, 22.5% completed; Piegan unit, 83.5% completed; Flathead project (Jocko division), 84% completed; Mission division, 11.6% completed; Pablo division, 36.5% completed; Polson division, 9.9% completed; Post division, 35% completed; Fort Peck project, no work during month; Huntley project, 96% completed; Milk River project, 12% completed; Sun River project, 9% completed; Fort Shaw unit, completed. *Montana-North Dakota.*—Lower Yellowstone project, 95% completed. *Nebraska-Wyoming.*—North Platte project, 82% completed. *Nevada.*—Truckee-Carson project, 69.5% completed; Lahontan dam and flume in Carson river, completed. *New Mexico.*—Carlsbad project, completed. *New Mexico-Texas.*—Rio Grande project, preliminary work; Leaseburg unit, completed. *North Dakota.*—Missouri river pumping project (Buford-Trenton unit), 38% completed; Williston unit, 64% completed. *Oregon.*—Umatilla project, 80.9% completed. *Oregon-California.*—Klamath project, 71% completed. *South Dakota.*—Belle Fourche project, 93.6% completed. *Utah.*—Strawberry Valley project, 64% completed. *Washington.*—Okanogan project, completed; Yakima project (storage unit), 17.5% completed; Sunnyside unit, 93% completed; Tieton unit, completed. *Wyoming.*—Shoshone project, 49.8% completed.

Streets and Roads

Sacramento.—The State Highway Commission has awarded contracts for sections of the state highway aggregating 56 miles in length, as follows:

In Madera county, an asphaltic oil road from the Merced county line to a point one mile south of California, a distance of 6.8 miles, the job going to the Worswick Street Paving Co. of Fresno, whose bid was $31,831; an asphaltic oil road from the Fresno county line to Madera City, a distance of 9.9 miles, the job going to the Worswick Street Paving Co. of Fresno, whose bid was $45,557. In Merced county, an asphaltic oil road from the Stanislaus county line to Arena, a distance of 9.6 miles, the job going to the Worswick Street Paving Co. of Fresno, whose bid was $50,343. In Fresno county, an asphaltic oil road from Fresno City to the Madera county line, a distance of 9.6 miles, the job going to the Worswick Street Paving Co. of Fresno, whose bid was $42,268. In Stanislaus county, an asphaltic oil road from the south boundary of the county to a point 1½ miles north of Ceres, the job going to E. O. Burge, of Sacramento, whose bid was $57,322. In San Diego county, an asphaltic

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oil road from San Diego to Encinitas, a distance of 8.6 miles, the job going to M. L. Curtis & Co., of South Pasadena, whose bid was $49,934.

The State Highway Commission has announced that it will call for bids on two contracts for portions of the state highway to be constructed under the $18,000,000 bond issue, including construction of a road from the Sylvan school on the Auburn road, in Sacramento county, thence going to the Placer county line and on to Lincoln. The road will have a cement base, and the surface will be of bitumen.

The other route for which a contract will be let is in Merced county, and will be constructed between the town of Arena and Merced city. This road will also be of high-class construction. The next route for which bids will be called starts at El Rancho Rincon, at the Santa Barbara-Ventura line. It then follows the Rincon route. The State Highway Commission has indicated that the route it will select, connecting the San Joaquin valley with the bay, will run from the San Joaquin county line through the towns of Livermore and Haywards to the Oakland line.

Marysville.—The Chico Construction Co. has completed three miles of the Morrison Crossing-Marysville section of the state highway.

Lodi.—The San Joaquin county supervisors are considering the construction of a new road between Lodi and Acampo which will include a new bridge across the Mokelumne river.

Martinez.—Plans have been completed for the construction of a boulevard to the summit of Mount Diablo. E. C. Brown is county surveyor.

Oakland.—Plans and specifications have been completed by the county supervisors for the new boulevard through Niles canyon. P. A. Haviland is county surveyor.

Truckee.—Gillett, Montgomery & Tracy, of Los Angeles, have commenced work on 13 miles of California state highway from Donner to Lake Tahoe.

Railways

San Francisco.—Sacramento Valley Electric Railroad Co. has been granted permission by the Railroad Commission to issue 30,000 shares of preferred stock amounting to $3,000,000 and common stock to the amount of $750,000. An electric railway will be built from Red Bluff to Woodland with an extension to Dixon and a branch line to Williams.——State Harbor Commission is preparing plans for the extension of the belt railroad from Clay to Harrison streets.——Mill Valley & Mt. Tamalpais Scenic railway has asked the Railroad Commission for authorization to issue 1500 shares of capital stock to provide funds for contemplated improvements and extensions.——The California, Shasta & Eastern Railway Co. has been incorporated, authorized capital stock of $600,000, of which $32,000 has been subscribed. The incorporators are S. E. Bretherton, Felix S. Smith, W. T. Barnett, Paul McCarthy, F. D. Madison, Platt Kent, and V. W. Vincent. The incorporators represent the Afterthought Copper Mining Co.'s interests, which owns and operates a mine and smelter at Ingot, in Shasta county. They have purchased the Anderson & Bella Vista railroad, which is 16 miles long, and will build a 12-mile extension from Bella Vista to Ingot.——Local United States Army officers have asked permission of the higher officials to build a double-track electric railroad to operate through the Fort Mason military reservation to connect with the Polk street line of the United Railroads.

Oakland.—A mortgage of $5,000,000, dated July 1, has been filed by the San Francisco, Oakland Terminal Railways to the California Trust Co., to provide funds for carrying on extensive improvements.

Chico.—The Northern Electric Co. is contemplating the construction of extensions from Chico to Richardson Springs through the Cohasset country through Forrest ranch, Berdans, and Lomo to Butte Meadows, and another to Nimshew over the Magalia ridge.

Truckee.—The Southern Pacific Co. has awarded a contract to the Utah Construction Co. for grading and double-tracking the line from Iceland to Winsted.

Panama Canal

Estimates of excavations remaining to be done after July 1 to complete the canal show an increase of 16,903,000 cu. yd. over the estimate of July 1, 1911. On the Atlantic division the increase is 295,000 cu. yd., prin-

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cipally to provide for silting in the finished channel not covered by the estimate of July 1, 1911. In the Central division an increase of 4,615,000 cu. yd. is made to provide for an extension, slides, and changes in the Obispo diversion. The Pacific division has an increase of 11,993,000 cu. yd., of which 3,199,000 cu. yd. are to cover excavations in the canal prism, in the locks and dams, and silting in the finished channel which has become necessary since the estimates of July 1, 1911. The remainder, 8,794,000 cu. yd., is for the newly begun excavations for the dry-dock, coaling station, and terminal at Balboa. The grand total of canal excavation to August 1, 1912, was 175,901,052 cu. yd., leaving to be excavated 36,325,948 cu. yd., or about one-sixth of the entire amount necessary for the completed canal. The total excavation for July was 2,633,437 cu. yd., as compared with 2,518,982 cu. yd. in the corresponding month of 1911.

Following are the names of railroads interested in the Panama canal government bill and the competing steamer lines which they control:

Southern Pacific Co.—Atlantic Steamship Lines, New York to New Orleans and Galveston; Pacific Steamship Lines, San Francisco to Marshalfield, Sacramento, and Oakland; New Orleans-Havana Line; Pacific Mail Steamship Co. (China and Japan); San Francisco & Portland Steamship Company.

Pennsylvania Railroad.—Baltimore, Chesapeake & Atlantic steamer line; Maryland, Delaware & Virginia steamer line; Montauk Steamship Co.; Erie & Western Transportation Company.

New York Central & Hudson River Railroad.—Fulton Navigation Co.; Ragnette Lake Transportation Co.; Rutland Transit Co.; Mutual Transit Co.; Mackinac Transportation Co.; Western Transit Company.

Grand Trunk Railway System (British system).—Canada Atlantic Transit Co.; Grand Trunk Pacific Steamship Company.

Canadian Pacific Railway (British system)—Canadian-Australian Royal Mail service; Royal Mail Steamship Line (Atlantic); Great Lakes service.

Great Northern Railway.—Great Northern Steamship Co.; Northern Steamship Company.

New York, New Haven & Hartford Railroad.—Eastern Steamship Corporation, consisting of Maine Steamship Co., Metropolitan Steamship Co., Eastern Steamship Co.; New England Steamship Co., consisting of Fall River Line, New Bedford Line, Providence Line; Merchants' & Miners' Transportation Company.

Seaboard Air Line and Southern Railway.—Jointly control Baltimore Steam Packet Company.

Southern Railway.—Chesapeake Steamship Company.

Norfolk & Western Railway, Atlantic Coast Line, Chesapeake & Ohio Railway, Southern Railway.—Jointly control Old Dominion Steamship Company.

Central of Georgia Railway.—Ocean Steamship Co. of Savannah.

Atlantic Coast Line and Florida East Coast Railway.—Jointly control Peninsula & Occidental Steamship Company.

Erie Railroad.—Union Steamboat Line.

Lehigh Valley Railroad.—Lehigh Valley Steamship Company.

Delaware & Hudson Co.—Lake George Steamboat Co.; Lake Champlain Transit Co.

Miscellaneous Engineering Construction

San Francisco.—An amended plan of the proposed bridge over Suisun bay for the Oakland & Antioch Railroad Co. has been completed. The bridge will consist of two spans, each 400 ft. long, with a clearance of 72 ft. above high water, and a third span, which will be the draw, having a lift supporting a further clearance of 140 feet.

Los Angeles.—The Water Board has instructed William Mulholland, chief engineer, to prepare plans and specifications for the construction of two pipe-lines, one having a capacity of 1000 miners' inches and the other 6500 miners' inches to be used for distributing the water confined in the San Fernando reservoir. The Board has recommended the sale of the aqueduct's cement plant at Monolith. The price has been fixed at $550,000 to the city and $800,000 to any private interest. The Los Angeles Aqueduct Advisory Board has abandoned temporarily plans for building the second unit of San Francisquito power house No. 1 for the reason that sufficient funds are not available.

Oakland.—The city council has appropriated $35,000 for the construction of a con-

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crete bridge to replace the old wooden structure and connecting the old city with the district east of Lake Merritt at Eighth street.

Martinez.—The town trustees have let a contract to the Mervy-Elwell Co. for enlarging the channel at a cost of $1400.

Victor (San Joaquin county).—Contract to build a bridge across the Mokelumne river has been let to Jenkins & Wells at a cost of $23,422.

Salinas.—John M. Gardner, of Los Angeles, is at the head of a new cement company recently incorporated for $2,000,000 to build a new cement plant at this point.

Los Angeles.—The city council has passed an ordinance providing for the improvement of streets, lowering the grade, and other necessary work preparatory to the construction of the Broadway tunnel.

Long Beach.—City of Long Beach will issue $1,500,000 in bonds for various civic improvements, including new piers, sewers, and various harbor improvements.

Phoenix, Arizona.—Southern Pacific Co. will build a new roundhouse and machine-shops at this point, at a cost of approximately $200,000.

San Diego.—Work has commenced on new harbor improvements which will ultimately cost $1,000,000. E. M. Capps is harbor engineer.

Auburn.—The Pacific Portland Cement Co. will erect a roundhouse and machine-shop at this point, preparatory to reconstruction of its portland cement plant.

Lodi.—H. K. Marshall and W. H. Graham of Los Angeles are about to commence the installation of a plant at this point for the manufacture of concrete pipe for irrigating purposes.

Fairfield (Solano county).—The Board of Supervisors will build three new concrete bridges to replace wooden bridges at present in use.

Yuba City.—Levee District No. 1 has awarded a contract to the Ross Construction Co. for the installation of 4700 yd. of material for a new levee.

Washington, D. C.—Governor of California has been officially notified of the intention of the Federal Government to make a comprehensive survey of the San Joaquin river and tributaries at a cost of $64,000, providing the state of California will pay half of the total cost.

Oroville.—The Chico Construction Co. has been awarded contract for the construction of reinforced concrete and steel bridges over Lindo channel at a price of $12,894.

Seattle.—The Seattle Port Commission has made a contract with the Pacific Terminal Co. of New York providing for harbor improvements to be made at a cost of $3,100,000.

Petroleum

The United States Geological Survey has made a report of the total production of petroleum in the United States in 1911 which shows an increase of nearly 11,000,000 bbl. as compared to 1910. The total output for California for 1911 is given as more than 81,000,000 bbl. Productions in California, Oklahoma, and Louisiana show marked increases, while the production for Illinois and Ohio show decreases. Total production in the United States since 1901 is as follows:

	Barrels.
1901	60,389,194
1903	100,461,337
1905	134,717,580
1907	166,095,335
1909	183,170,874
1911	220,449,391

California gross production, stocks on hand, and shipments for July are as follows:

GROSS PRODUCTION

Fieid.	Fuel.	Gross.
Coalinga	63,391	1,638,416
Kern River	175,000	1,072,267
McKittrick	28,201	576,682
Maricopa	45,749	464,878
Midway	72,480	2,153,751
Lost Hills	7,800	114,033
Santa Maria	11,750	460,593
Fullerton	4,890	475,559
Salt Lake	2,490	201,085
Whittier	2,675	55,595
Coyote	490	90,197
Los Angeles City	1,500	33,342
Summerland	600	4,950
Newhall	500	10,810
Ventura	5,310	64,526
Total	422,826	7,436,684

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STOCKS

	Field.	Pipe-line.	Total.
Coalinga	373,274	2,740,097	3,113,371
Kern River	376,162	28,287,629	28,663,791
McKittrick	110,250	759,659	869,909
Maricopa	292,998	228,479	621,477
Midway	399,920	1,361,470	1,761,390
Lost Hills	18,200	151,571	169,771
Santa Maria	360,144	316,637	676,781
Fullerton	67,490	118,126	185,616
Salt Lake Field	129,818	38,245	168,063
Whittier	31,590	.....	31,590
Coyote	29,918	.....	29,918
Los Angeles	15,000	454,898	469,869
Newhall	3,631	.....	3,631
Ventura	42,496	27,714	70,210
Outside	.....	8,654,788	8,654,788

SHIPMENTS

During July 1912 there were shipped from the San Francisco district 12,532,968 gal. of illuminants, valued at $621,165; 7,419,452 gal. of residuum, valued at $138,927; 14,049,000 gal. of lubricating oils, valued at $26,607; gasoline, 459,677 gal., valued at $62,011; asphalt, 4254 tons, valued at $56,962.

The largest consumers were: Illuminating —China, 6,000,000 gal.; Japan, 5,896,000 gal.; Hawaii, 341,059 gal. Residuum—Hawaii, 2,016,000 gal.; Alaska, 1,722,414 gal. Crude —Hawaii, 5,124,000 gal.; Chile, 4,242,000 gal.; Panama, 3,738,000 gal. Gasoline—Hawaii, 406,025 gal. Asphalt—Canada, 2600 tons.

Revised list of California oil dividends for June is as follows:

	Rate.	Amount.
Amalgamated	$1.0000	$ 50,000.00
Caribou	0.0100	8,070.30
Central	0.0150	15,750.00
Claremont	0.0100	5,000.00
Columbia	0.0100	9,992.26
Del Rey	0.0050	3,627.45
Euclid	0.0050	1,750.00
Home	0.0010	5,000.00
Monte Cristo	0.0250	12,500.00
Mount Diablo	0.0010	5,000.00
New Pennsylvania	0.0050	2,500.00
Paraffine	0.0100	3,000.00
Premier	0.0100	10,000.00
Rice Ranch	0.0150	4,500.00
Record	0.0500	10,000.00
S F. McKittrick	0.1000	5,000.00
Sauer Dough	0.0150	15,000.00
Section 25	0.5000	20,000.00
Shawmut	0.0200	10,000.00
Silver Tip	0.0500	3,500.00
State Consolidated	0.0067	5,000.00
Traders	0.0060	9,000.00
Union	0.0060	184,743.60
Union Provident	0.0060	91,402.03
United Petroleum	0.0060	48,450.60
Western Union	0.0100	5,000.00
W. K.	0.0300	15,000.00
Total		$556,086.24
Mexican Pet. Ltd., pfd.	0.0067	80,000.00
Grand total		$636,086.24

The complete list for July includes:

	Rate.	Amount.
Amalgamated	$1.0000	$ 50,000.00
Caribou	0.0100	8,070.30
Claremont	0.0100	5,000.00
Central	0.0075	7,500.00
Columbia	0.0100	9,992.26
Del Rey	0.0050	3,977.45
Empire	0.5000	100,000.00
Fullerton	0.0500	30,000.00
Home	0.0100	5,000.00
Monte Cristo	0.0050	12,500.00
Mount Diablo	0.0100	5,000.00
Nevada County	0.0600	15,000.00
New Penn	0.0050	5,000.00
Olinda Land	0.0075	7,500.00
Paraffine	0.0100	3,000.00
Peerless	0.2500	25,000.00
Record	0.0100	5,000.00
Rice Ranch	0.0150	4,500.00
S. F. & McKittrick	0.0100	5,000.00
Sauer Dough	0.0075	2,992.50
Section 25	0.5000	20,000.00
State Consolidated	0.0100	5,000.00
Traders	0.0060	9,000.00
Union	0.0060	184,743.60
Union Provident	0.0060	91,402.02
United Petroleum	0.0060	48,450.60
Western Union	0.0050	5,000.00
W. K.	0.0200	10,000.00
Total		$683,628.73
Mexican Pet. Ltd., pfd.	0.002-3	80,000.00
Grand total		$763,628.73

According to a preliminary report issued by W. H. Storms, state mineralogist, the petroleum output of California in 1911 was $37,920,820. This includes that sold or in storage on December 31. The value of oil consumed in the field as fuel is given as $2,631,268. The report covers the hydrocarbons, which include petroleum, natural

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gas, and bituminous rock, exclusive of asphalt made from oil and all refined products, the total value of which during 1911 was $41,161,226. The following is the distribution by counties:

Kern	$20,373,344
Fresno	9,344,085
Orange	4,097,980
Los Angeles	2,329,180
Santa Barbara	3,305,103
Ventura	352,735
San Joaquin	114,433
Sacramento	83,890
Santa Cruz	80,373
Solano	40,274
San Luis Obispo	30,376
Santa Clara	8,505
Kings	800
Humboldt	150

The output is divided as follows:

Petroleum sold in 1911, or in storage December 31	$37,920,820
Petroleum used as fuel in the field	2,631,268
Natural gas	491,859
Bituminous rock	117,279
Total	$41,161,226

operated by the Rice Ranch Oil Co., has installed two Bessemer gas-compressors for the manufacture of gasoline from natural gas. The character of the gas is such that approximately 2.5 gal. from 1000 cu. ft. of gas can be produced. The total gas output from the wells is approximately 2,000,000 cu. ft. per day.

Bakersfield.—Kern County Oil Men's Protective Association, under direction of Mr. Foraker, has already cemented more than 50 wells and is doing much good in dealing with the water situation.

Brea.—The Pacific Gasoline Co. has increased the capacity of its plant by adding two 101-hp. compressors. These machines are of the Ingersoll-Rand type and will be belted to Western gas-engines.

Los Angeles.—The Pacific Light & Power Co. has installed two 250-hp. Buckeye natural-gas engines for generating electricity. The present output is 300 kw. If the plant is successful the company expects ultimately to convert the greater part of its auxiliaries from steam to natural-gas engines, using gas from the Midway field. Edward Woodbury is engineer in charge.——Natural gas

PETROLEUM SHIPMENTS TO ALASKA.

	Eleven months ended May		
	1910. Gallons.	1911. Gallons.	1912. Gallons.
Crude (including all natural oils without regard to gravity	13,825,400	15,088,576	9,131,198
Naphthas and all lighter products of distillation	710,300	802,487	1,943,640
Illuminating oil	580,027	502,103	426,774
Lubricating and heavy paraffine	82,201	114,134	97,654
Residuum and all others from which light bodies have been distilled	194,641	342,530	3,470,103
Total	15,392,668	16,849,830	15,069,369

San Francisco.—The General Petroleum Co. is reported to have purchased property of the Bear Creek Oil & Mining Co. in the north Midway field for about $1,500,000. The property consists of 420 acres of oil land which is at present producing about 25,000 bbl. per month.——The Indian Oil Co. has let a contract to the Western Pipe & Steel Co. for the construction of ten steel oil-storage tanks and a steel gas-holder for its plant in Martinez for the sum of $57,350, the work to be completed by December 15, 1912.

Santa Maria.—The Purity Gasoline Co., pipe-line under construction for the Midway Gas Co. is completed for a distance of 80 miles. Three gangs of men are employed. W. E. Barrack is engineer in charge, and H. N. Daugherty is field superintendent. The present pipe-line is 12 in. diameter, and the second, upon which work is soon to be commenced, will be 16 in. diameter. The natural rock-pressure at the wells is between 1200 and 1400 lb. per square inch, so pumping plants will not be required. The total cost of the pipe-lines will be approximately $3,000,000.

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Hints on Practice

Characteristics of Good and Bad Glue*

By JOHN SCOTT

GLUE should always be purchased upon test—and coal should be purchased in like manner. The woodworker who does not purchase coal, glue, oils, varnishes, and some other articles in that manner is not doing as he should. Ten to one, he is losing money by not purchasing all those commodities 'on test.' But if glue is to be purchased according to the result of some tests, what are those tests, and how are they carried out? What must be done to a lot of glue in order to determine, without guessing, just what that lot of glue is worth to the woodworker?

There are at least ten tests to which glue should be subjected, which are as follows: A close inspection; measuring moisture; analyzing the ash; noting the odor; acid or alkaline; grease test; viscosity test; the jelly strength; joint strength; and the spreading quality.

A number of these tests can be carried out with very little apparatus. Others, like the ash analysis, cannot be made without instruments and chemical knowledge. The examination should be to see how the glue breaks. If the surface is free from bubbles (dry glue) and breaks evenly and glossy, it is good. The thinner the sheets (cut), generally, the better the glue. Reject the glue which smells putrid or has some other bad odor. The best glue smells good enough to eat. Glue should be neither very acid nor very alkaline. Neutral is best.

To test for grease—and that substance is always damaging when present in any considerable quantity—drop a little soluble aniline on a brushful of glue, wipe the brush in circles upon a bit of paper, then suddenly draw the brush across the paper, and see if there are any white spots left in the path of the brush. White spots mean the presence of grease, and the more spots counted, the more grease.

To test the viscosity or 'body' of glue, it is permitted to run through a certain sized hole at a temperature of about 150°F. Solutions for test should always be made of 25 parts dry glue in 100 parts (by weight) of pure water at the temperature named. The instrument is rated by noting how long a time is required for a certain quantity of water to run out, then the glue is tried and the time of each sample noted.

Testing jelly strength of glue needs special apparatus. The foam test may be made by stirring some glue with an ordinary egg-beater for half a minute and then noting the percentage of foam. If the foam is permanent, the glue might be better.

The joint test as usually made—whereby two boards are glued together and then pried apart with a chisel—is absolutely worthless. The joint test should be made on oak wood, glued together endwise, and then pulled apart in a testing machine, and the stress noted in pounds.

The spread test consists in determining the amount of dry glue necessary to cover a given area of wood. This test is favored by veneer workers. To make it, use a certain amount of dry glue dissolved in the same amount of water for each test and used at the same temperature of square feet of surface the glue will cover.

When it is known that glue will be accepted upon the viscosity test alone, some dealers and manufacturers seem inclined to 'load' the glue by adding substances which increase the viscosity but do not add to the value of the glue.

To detect the 'loading' of glue, dissolve one part of dry glue in four parts (by weight) of water, by soaking for at least 24 hours therein; then bring the weight up to 17 parts by adding grain alcohol. The mixture, after thorough stirring, may be allowed to settle; the residue is then filtered, and well washed with alcohol and water, one part in three. After being dried out, the residue is weighed, and its percentage, compared with the original weight of the glue, is the amount of loading and other non-gelatinous and worthless material in the glue.

By putting the glue through as many of the above tests as possible, the user will certainly know a whole lot more regarding a certain sample than he would if the foreman merely looked at the glue and then 'guessed' at its quality.

*Abstract from *Mechanical World*, July 26, 1912.

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Engineers' Note Book

The Spouting of Concrete

ACCORDING to *Chain Belt*, for successful operation of the gravity systems for conveying and distributing concrete, one of the most necessary things is the proper mixing of the ingredients. Having given the proper proportions to the ingredients it is absolutely necessary that enough water be added to the conglomerate to produce a specific gravity such that the rock is held in suspension. The mixture will then flow like a thick gravy with no sign of excess water; in other words, it should have a saturated amount of water and no more. This particular mixture is surprisingly slippery and flows readily around all steel.

In placing concrete by the gravity system there are three operations: The mixing of the ingredients, stone, sand, and cement, in a suitable batch mixer; hoisting of the mixed concrete by skip to an elevated hopper; and the transferring of the concrete through pipes leading from this hopper to the point where it is desired to be poured. The following general instructions for operating a spouting system may be of value:

1. Run about 10 ft. of water in skip.

2. Charge mixers, using mostly sand with the cement and plenty of water.

3. Run up skip with water and drop at once, following as quickly as possible with a charge of concrete.

4. Run the mixture so that it may have the consistence of a thick gravy. Thus when it levels off, the rock is seen held in suspension. If it stands up when dumped in skip, it is too thick; if it levels off and shows 1 in. of water, it is too thin.

5. There should be a man in the tower to operate the concrete gate on the hopper to regulate the flow of concrete through the pipes. The stream should fill about one-third of the conveyor pipe and the charge should be so timed that the stream will be as continuous as possible.

6. The continuous and successful running depends on the uniform mixture. Be careful not to get it too thin. After a shut-down of over 10 minutes, flush the pipe by sending 10 ft. of water up in the skip.

7. At the end of the day's run clean out the mixers with two charges of water. Send these through the pipes.

8. All pipe joints should be oiled with thick grease so as to prevent sticking.

It is in general not advisable for any contractor to use the gravity system for the first time on a job of less than 2500 cu. yd. However, it has been successfully used on jobs as low as 250 cu. yd. In these cases the apparatus was on hand and the men were familiar with its operation.

FORMULA for the friction of air in pipes, according to Frank Richards is:

D = diameter of pipe in inches.
L = length of pipe in feet.
V = volume of air delivered, in cubic feet per minute.
H = head or difference of pressure required to overcome friction and maintain the flow.

$$H = \frac{V^2 L}{10000\, D^5 a}$$

$$V = \sqrt{\frac{10000\, D^5 a H}{L}}$$

$$D^5 a = \frac{V^2 L}{10000 H}$$

$$L = \frac{10000\, D^5 a H}{V^2}$$

Values of a for wrought iron pipes.

Diam.		Diam.	
1	0.350	5	0.934
1¼	0.500	6	1.000
1½	0.562	8	1.125
2	0.565	10	1.200
2½	0.650	12	1.260
3	0.730	16	1.340
3½	0.787	20	1.400
4	0.840		

According to Jones and Laughlin handbook, the weight of a hexagon head and square nut together will equal that of a rod of iron in length five times the diameter of the bolt.

For square heads and nuts, six times the diameter.

For rose heads and square nuts, four times the diameter.

For upset bolts, allow 3½ diameters for upsetting.

For square heads and nuts, 9½ diameters of bolts before upset.

For hexagon heads and nuts, 7.9 diameters.

For upsetting, square head and nut and two round washers, 35 diameters.

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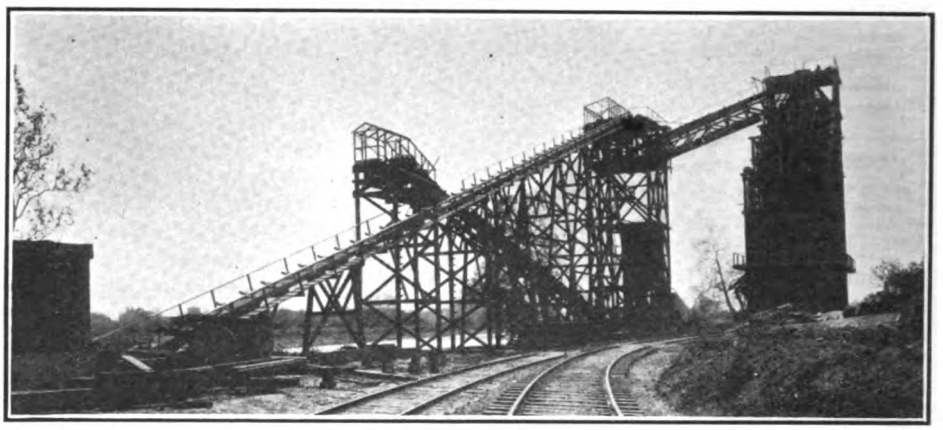
Industrial Progress

Modern Gravel Screening, Crushing, and Washing Plant

By J. A. BRIED

Thirty miles southeast of San Francisco, at Niles, California, a gravel crushing, screening, and washing plant was recently installed by the Niles Sand, Gravel & Rock Co., which embodies the latest and best practice in the design of this class of machinery. As it is one of the few plants of the kind on the Pacific Coast a description of its operation will be of interest. Howard C. Plummer, vice-president and engineer for the company, made an exhaustive investigation of plants in operation in the vicinity of Chicago, working under similar conditions, and was, therefore, enabled to embody the experience of many of the largest Eastern companies in the design of his own plant. The plans were made under Mr. Plummer's direction, and the plant was completed and placed in operation in June. The rated capacity is 1000 yd. of gravel per day, but the production thus far has ranged between 1200 and 1500 yd. daily.



GENERAL VIEW, CRUSHING, SCREENING, AND WASHING PLANT.

The gravel is taken from the river bed and banks by means of a Lidgerwood drag-line excavator and carried to a large concrete hopper by means of an incline surface tramway with steel bottom-dump cars, which are operated by a hoist erected on a turn-table on top of the main hopper. The incline tramway is erected on a portable trestle in order that its location with respect to the excavator may be altered to suit the position at which the excavator is operating. The hoist turns with the tramway, in order that it may exert a direct pull upon the hoisting rope without requiring the use of guide sheaves. Gravel is discharged from the main hopper by an automatic feeder to the main 30-in. troughing belt-conveyor which operates at an angle of 18 degrees and is 285 ft. long, centre to centre. This conveyor carries the gravel to a cross-conveyor 30 in. wide and 50 ft. centres, passing over the railroad spur track and delivers the material to a hopper with two compartments which divides the material in two parts. Water is added at this point, and the gravel, sand, foreign matter, and water is discharged by gravity into the first two screens. A battery of 10 screens, of the Meese & Gottfried conical type, effect a thorough sizing of the wet gravel, the discharge from one into the other being successive. Each screen is provided with a pipe nozzle, so that all rejections must pass through a spray of clean water before being discharged. These nozzles are so arranged that the water for giving the final washing to the rejections is not discharged in the bins, but follows and mixes with the material passing through the perforations in the next set of screens. This process is repeated between each stage of the screening, so that when the screening has been completed all the fine sand and water, together with all impurities, are led to the separators,

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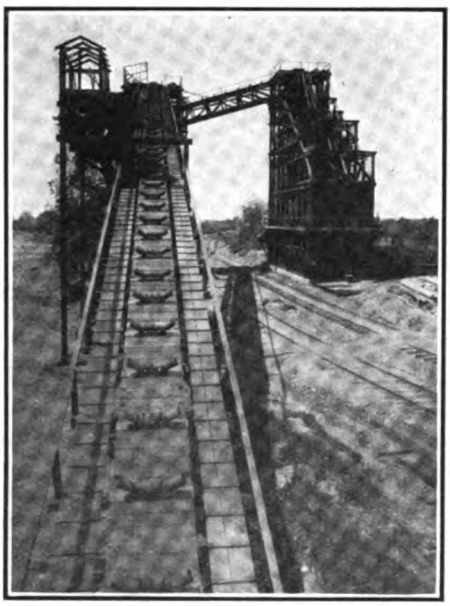
from which the water and impurities pass off through an overflow. The sand settles on the bottom and is automatically discharged into the sand-bin. The oversize or rejections from the first set of screens pass by gravity through a steel-lined chute between the bunkers and the conveyor trestle to the crusher bin, which is directly under the 30-



MAIN CONVEYOR, NILES SAND, GRAVEL & ROCK CO.

in. main belt-conveyor. The boulders pass through a heavy rack and pinion gate from the crusher-bin to the crushers. The broken rock discharged by the crushers is carried by a 24-in. belt-conveyor back to the 30-in. main conveyor for return to the screens for re-sizing. It will be noted that the process throughout is continuous and automatic, that the material is thoroughly screened and cleaned from all dirt or foreign matter. No material discharges to the various bins that has not been washed and accurately sized. Nothing is wasted; even the water used in washing is piped to the nearby orchards for irrigation purposes, while the dirt and impurities find use as a fertilizer. Five separations of various sizes of clean washed gravel are obtained which renders this material ideal for the various purposes for which it is employed. The loading bunkers are equipped with Meese & Gottfried quick-opening quadrant gates and balanced car-loading chutes. These are arranged on both sides of the bin, in order that a gate may be opened with one hand and the car-loading chute adjusted with the other. The gates are of the quick-opening type, and may be easily opened or closed against the pressure of the material in the bins by hand without excessive exertion. The loading spouts are carefully counterbalanced so that they may be manipulated with ease.

The company was fortunate in securing control of a large section of the river bed and adjoining lands. The deposit of gravel and sand is almost unlimited in quantity, as the spring floods renew every year as much as has been removed during the season. The gravel and sand is all of exceptionally fine quality and is remarkably free from any foreign matter, thus making it ideal for use in all forms of concrete construction. Shipping facilities at Niles are excellent for the distribution of their product to all parts of the country, as the tracks of both the Western Pacific and Southern Pacific pass through the property. The transmission, elevating, conveying, and screening machinery for the entire plant was manufactured by the Meese & Gottfried Co. of San Francisco and the results that have been obtained justify the high reputation that this company has always enjoyed for the design and construction of this class of machinery.

Mayari Steel

Mayari steel, according to the Pennsylvania Steel Co. is made from a low phosphorus Cuban ore containing nickel and chromium. By a slight modification of the open-hearth process this steel is produced without the necessity of adding the alloying elements in the furnace and ladle. Uniformity is thus secured in their distribution throughout the heat, and also in composition for all heats of any one grade of steel. In the natural rolled or forged condition it has from 8000 to 10,000 lb. higher tensile strength than a carbon steel of the same carbon content. It welds with difficulty, as is the case with all alloy steels. Under the accelerated sulphuric acid test for corrosion this steel shows 10 to 20% less corrosion than the low carbon basic open-hearth steels and also steels containing below 0.05% carbon and 0.10% manganese. Mayari steel may be heat-treated and case-hardened with excellent results.

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Personal

JOHN W. MCCALLUM has been appointed Harbor Commissioner to succeed the late George M. Hill.

HERBERT HAAS, consulting engineer, has opened offices at 524 Merchants Exchange building, San Francisco.

L. B. LUPPEN, of San Francisco, has been appointed mechanical engineer in the State Engineering Department at Sacramento.

ELMER DOVER, president of the Tacoma Gas Co., has been appointed manager of the Pacific Coast interests of H. M. Byllesby & Co. of Chicago.

CHARLES F. UEBELACKER, CHARLES N. BLACK, and WILLIAM VON PHUL have been admitted to partnership with Ford, Bacon & Davis, engineers, of New York.

JEROME NEWMAN, formerly assistant to Mr. Hood, chief engineer for the Southern Pacific Co., has been appointed chief engineer for the State Harbor Commission, succeeding A. V. Saph.

S. L. BERRY has resigned his position as chief engineer for the Joshua Hendy Iron Works and will engage in consulting practice with offices in the Rialto building, San Francisco.

THE President has appointed Maj. J. J. Morrow, Engineer Corps, U. S. A.; A. H. Brooks; Leonard M. Cox, civil engineer, U. S. N.; and C. M. Ingersoll to be members of the Alaska Railroad Commission. Major Morrow, who is chairman of the Commission, has recently been in charge of jetty construction at the mouth of the Columbia river; Mr. Brooks, vice-chairman, is chief of the Division of Mineral Resources, U. S. Geological Survey; Mr. Cox has been chief assistant in the Bureau of Yards and Docks at Washington, D. C.; and Mr. Ingersoll is a consulting civil engineer of New York. As the report made by the Commission will form the basis of future legislation regarding Alaska's transportation problems, their recommendations will be awaited with much interest.

Society Meetings

THE sixth annual convention of the Illuminating Engineering Society will be held at Niagara Falls, Ontario, Canada, September 16 to 19, 1912. Many notable papers will be read dealing with lighting in its various phases, and it is expected that this meeting will be the most important that this society has ever held.

Commercial Paragraphs

The WISCONSIN ENGINEERING CO., of Corliss, Wisconsin, has issued an attractive folder describing the Adams Wisconsin gas-engine. The Vix Engineering Co., Mills building, San Francisco, is Pacific Coast agent.

A. O. Krieger has resigned as publicity manager for the BUSCH-SULZER BROS. DIESEL ENGINE CO. of St. Louis, and has opened offices at 916 Victoria building, St. Louis, for the sale of the Tacchella oil-burning device.

The GENERAL FIRE-PROOFING CO., of Youngstown, Ohio, has published a 'Fire-Proofing Hand Book' dealing with the problems of low-cost fire-proofing construction based upon the use of the reinforcing materials known as 'self-sintering' and 'trussit.' Much valuable data are given on the subject of fire-proofing in general and on the various applications of the special product manufactured by the company.

MOORE & SCOTT IRON WORKS report continued success with their mechanical high-pressure burners. In the new system the shipowner is not required to equip his boilers with elaborate mixing and pre-heating chambers, with hollow cones, adjustable dampers, thimbles, and movable sleeves. A simple front constitutes the principal feature of the Moore & Scott system. It contains a concentric air-trunk, with lateral opening at its outer end, which projects concentrically within the second air-trunk carried by the furnace front, so arranged as to give the ingoing air a spiral motion. This arrangement not only insures perfect combustion, but prevents direct radiation backward to the fire-room, a most important detail where fire-rooms are congested and overheated. The Pacific Coast Steamship *Eureka* is one of the latest vessels equipped with the Moore & Scott system, and the results realized on the voyage just completed to Nome and return more than justified the company's expectations.

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